

Space for Development: US-Indian Space Relations 1955 -1976

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List of Abbreviations

AIR – All India Radio
ARIES - Aryabhata Research Institute of Observational Sciences
ATS - Application Technology Satellite
COSPAR – United Nations Committee on Space Research
CSAGI - Comité Spécial de l'Année Géophysique Internationale
DAE - Department of Atomic Energy
DRDL Defense Research Development Laboratory
DRDO – Defense Research Development Organization
ESCES - Experimental Satellite Communication Earth Station
GSFC – Goddard Space Flight Center
HCO – Harvard College Observatory
IASY - International Years of the Active Sun
ICSU - International Council of Scientific Unions
IGMDP – Integrated Guided Missile Development Program
IGY – International Geophysical Year
IIOE – International Indian Ocean Expedition
INCOSPAR – Indian Committee on Space Research
IQSY – International Year of the Quiet Sun
IRBM – Intermediate Range Ballistic Missile
ISRO – Indian Space Research Organization
ITU - International Telecommunication Union
NAS – National Academy of Sciences
NASA – National Aeronautics and Space Administration
NASDA – National Space Development Agency
OMC – Office of Munitions Control
PRL – Physical Research Laboratory
SAO – Smithsonian Astrophysical Observatory
SCOUT – Solid Controlled Orbital Utility Test System
SSTC – Space Science Technology Center
STEX – Static Test Evaluation Complex
TAG – Technical Advisory Group
TERLS – Thumba Equatorial Rocket Launching Station
TIFR – Tata Institute of Fundamental Research
UNCOPOUS - UN Committee on the Peaceful Uses of Outer Space
UNDP – United Nations Development Program
UPSO – Uttar Pradesh State Observatory
VSSC – Vikram Sarabhai Space Center

Summary

Through four case studies of technological systems – optical tracking of satellites, sounding rockets, instructional television through a geosynchronous satellite, and a launch vehicle--I explore the origins and development of the Indian space program from 1955 through 1976, a period critical in shaping the program's identity and its relationship to the state. Institutionalized, and constructed in different geographic regions of India, these systems were embedded in the broader political, economic, and social life of the country and served as nodes around which existing and new scientific and technological communities were formed. These organic, highly networked communities in turn negotiated and developed a space program to meet the social and strategic demands of a new modernizing nation state. That modernizing program was, in turn, embedded in a broader set of scientific, technological and political relationships with industrialized countries, above all the United States.

The United States' cooperation with India began with the establishment of tracking stations for plotting the orbits of artificial satellites. Cognizant of the contributions made by Indian scientists in the field of astronomy and meteorology, a scientific tradition that stretched back several decades, the officials and the scientific community at NASA, along with their Indian counterparts outlined a cooperative program that focused on the mutual exploration of the tropical space for scientific data. This initial collaboration gradually expanded and more advanced space application projects brought the two democratic countries, in spite of some misgivings, closer together in the common cause of using space sciences and technologies for developing India. In the process India and the United States ended up coproducing a space program that responded to the ambitions of the postcolonial scientific and political elite of India. The global Cold War and the ambiguities, desires and tensions of a postcolonial nation-state vying for leadership among the newly decolonized states in the Afro-Asian region are critical for understanding the origins and

the trajectory of India's space program. Without this political context and the construction of a transnational web of relationships, it is highly unlikely that the Indian scientific and technological elite, along with their industrial and political partners, would have succeeded in putting India on the space map of the world.

Chapter I: Introduction

Few today contest the significance of India's rapid economic expansion, or question the growing importance of India in world affairs. As an emerging global power its nuclear and space ambitions have grown by leaps and bounds. Starting as a space science enterprise in the late nineteen fifties with meager resources India now looks towards an ambitious space program, including human space flight, in the coming decades. Undoubtedly, the Indian space program is one of the success stories of modern India. Many countries made contributions at different stages of its evolution to make India a global player in space. Among these countries, the United States by far played a key role in institutionalizing and establishing a space program for India.

The United States' cooperation with India began with the establishment of tracking stations for plotting the orbits of artificial satellites. Cognizant of the contributions made by Indian scientists in the field of astronomy and meteorology, a scientific tradition that stretched back several decades, the officials and the scientific community at NASA, along with their Indian counterparts outlined a cooperative program that focused on mutual exploration of the tropical space for scientific data. The cooperation started in the early 1960s with the loan of sounding rockets, launchers and the training of Indian scientists and engineers at selected NASA facilities. This initial collaboration gradually expanded and more advanced space application projects brought the two democratic countries, in spite of some misgivings, closer together in the common cause of using space sciences and technologies for developing and modernizing India. In the process India and the United States ended up coproducing a space program that articulated the sentiments of the postcolonial scientific and political elite of India.

Conversely, the experience with India imparted a new meaning and architecture of what a space program should be in developing countries in Asia and Latin America. The global Cold War and the ambiguities, desires and tensions of a postcolonial nation-state vying for leadership among the newly decolonized states in the Afro-Asian region forms the essential backdrop for understanding the origins and trajectory of India's space program.

The development of a space program in India is contextualized here in the framework of the United States' relations with India beginning in nineteen fifties. Two interconnected themes frame the dissertation. First, the history and discourse of modernization and development will be used to situate U.S.-India foreign relations in the postwar period. In the wake of the Bandung conference (1955) leaders of newly decolonized states hoped to construct a third, 'non-aligned' force in the international arena that was independent of the competing ideologies of progress that defined Cold War rivalry. Bandung also became a platform for developing nations to embrace the mantra of rapid modernization and self reliance to leapfrog into modernity. This movement was not always welcomed by the U.S. government which remained at arms length from India until its defeat in a border war with China (1962) and the Chinese nuclear test (1964). The Chinese threat was given a global dimension: the PRC would become the model for newly-liberated countries in the 'Third World.' To counter this threat the United States -- and this is the second main theme -- hoped both to accelerate India's emergence as a major regional power and to use its technological advantage to divert India's nuclear and missile ambitions into civilian space projects. US-India cooperation in space based technologies was seen as a prestigious and useful alternative for the needs of the country. The Indian scientific and political elite, mindful of the

evolving non-proliferation regime orchestrated by the US, sought to ‘indigenously’ develop their own space technologies by creating new institutions domestically and through the transnational traffic of experts, systems and software. These two themes are the scaffolding for understanding the evolution of United States-India relations in space science and technology.

There is a limited non-academic and academic literature on the Indian case. Gopal Raj’s popular *Reach for the Stars* is a good account of how India developed its launch vehicle capability.¹ Angathevar Baskaran has published key journal length articles focusing on policy aspects of space applications and technology.² Amrita Shah’s recent work on Vikram Sarabhai³ and the economic history of the Indian space program by U. Sankar⁴ offer new insights into the history of India’s space program. These works, however, rely mostly on sources published by the Indian government and newspaper reports and do not bring to light the early stages of cooperation in any detail nor do they tie developments with broader domestic and international political realities.

This work has intellectual moorings in John Krige’s studies on science, technology and international affairs.⁵ His efforts at integrating the history of technology

¹ Gopal Raj, *Reach for the Stars: The Evolution of India's Rocket Programme* (New Delhi: Viking, 2000).

² Angathevar Baskaran, "Competence Building in Complex Systems in the Developing Countries: The Case of Satellite Building in India," *Technovation* 21, no. 2 (2001): 109-21; Angathevar Baskaran, "Technology Accumulation in the Ground Systems of India's Space Program: The Contribution of Foreign and Indigenous Inputs," *Technology in Society* 23, no. 2 (2001): 195-216; Angathevar Baskaran, "From Science to Commerce: The Evolution of Space Development Policy and Technology Accumulation in India," *Technology in Society* 27, no. 2 (2005): 155-79.

³ Amrita Shah, *Vikram Sarabhai, a Life* (New Delhi: Penguin, 2007).

⁴ U. Sankar, *The Economics of India's Space Programme: An Exploratory Analysis* (New Delhi: Oxford University Press, 2007).

⁵ John Krige and Kai-Henrik Barth, *Global Power Knowledge: Science and Technology in International Affairs, Osiris*, Volume 21, Chicago: University of Chicago Press, 2006; John Krige, *American Hegemony and the Postwar Reconstruction of Science in Europe*

literature with international affairs have opened new vistas to explore the use of science and technology as instruments of United States foreign policy. The study also draws inspiration from the scholarly work of Raman Srinivasan who first attempted to connect the history of India's space program, particularly the origins and development of the Indian National Satellite (INSAT), with the greater currents of the Cold War and to deeper Indian intellectual and cultural traditions.⁶ Recent work by space historian Asif Siddiqi has indicated new ways of studying the evolution of space programs in emerging space powers.⁷

In this introduction I will provide the international and domestic context for situating and understanding the microevolution of India's space developments. I will do this by giving a background to US-India foreign relations and describing the origins of a national space agenda and its rationale in the eyes of key members of Indian national elites, mainly Jawaharlal Nehru, Homi J. Bhabha and Vikram Sarabhai – namely as an instrument of modernization. In a climate of Indian leaders' outspoken "neutrality" and penchant for rapid modernization through the application of science and technology, the United States government, through different agencies and institutions, levered its technological preeminence to forge an alliance with the Western trained indigenous elite and to channel India toward a liberal democratic and capitalist system. The Indian elite, however, mindful of their newly won sovereignty had to walk a tight rope not to get

(MIT Press, November 2006, (cloth), MIT Press, September 2008; John Krige, "NASA as an Instrument of U.S. Foreign Policy," in *Societal Impact of Spaceflight* Steven J. Dick and Roger D. Launius, eds., (Washington DC: NASA SP-2007-4801), pp. 207-18.

⁶ Raman Srinivasan, "No Free Launch: Designing the Indian National Satellite", in *Beyond The Ionosphere: Fifty Years of Satellite Communication*, Andrew J. Butrica, ed., (Washington, D.C.: NASA SP-4217, 1997).

⁷ Asif Siddiqi, "Competing Technologies, National(ist) Narratives, and Universal Claims: Toward a Global History of Space Exploration," *Technology and Culture* 51, no. 2 (April 2010): 425-443.

entangled in East-West conflict while at the same time being selectively porous to ideas of governance and socio-economic planning, and scientific and technological aid aimed at development. This inbuilt tension in relations between two unequal powers in the climate of global Cold War and the destination, albeit different, desired by them shaped the trajectory of the Indian space program.

US-India Foreign Relations

Scholars who have studied the history of Indo-US relations over the last five decades have almost exhausted the English vocabulary to describe the tensions that prevailed between the two largest democracies.⁸ In the Cold War that ensued between the U.S. and the USSR soon after the independence of India and Pakistan from British rule in 1947, the U.S. favored an alliance with Pakistan owing to its strategic location - bordering the USSR, China and the Middle Eastern countries. The ensuing partnership was intended to counter any communist expansion from China or the USSR into the South Asian region. While India espoused the policy of non-alignment, Pakistan sided with the United States, joined the Baghdad Pact and the Southeast Asia Treaty Organization (SEATO), and received extensive military supplies. This close alliance between the United States and Pakistan resulted in increased alienation between US and India and in the words of Dennis Kux, former Foreign Service South Asia specialist, the relations were “uneven -- on occasion friendly, sometimes hostile, but, more often, just

⁸ Dennis Kux, *Estranged Democracies: India and the United States, 1941-1991* (New Delhi: Thousand Oaks: Sage Publications, 1994); Gary K. Bertsch, Seema Gahlaut, and Anupam Srivastava, *Engaging India: US Strategic Relations with the World's Largest Democracy* (New York: Routledge, 1999); H.W. Brands, *India and the United States: The Cold Peace* (Boston: Twayne Publishers, c1990); Andrew J. Rotter, *Comrades at Odds : the United States and India, 1947-1964* (Ithaca, N.Y. : Cornell University Press, 2000); Robert J. McMahon, *The Cold War on the Periphery : the United States, India, and Pakistan* (New York : Columbia University Press, 1994).

estranged.”⁹ India’s openly declared “neutrality” at the Bandung conference was the starting point for this estrangement.

Bandung

Martinique scholar, Vijay Prashad in his book *The Darker Nations: A People's History of the Third World* reminds us that “Third World” was not a place but a project. The project was aimed at designing a “third” better world, at a time when competing systems, capitalist and communist, vied for supremacy with the backdrop of a possible nuclear annihilation. This short lived “project” was initiated by leaders of Africa, Asia and Latin America when they met in 1955 at Bandung -- a densely populated city located on Western Java in Indonesia, to give hope and to fulfill the aspirations of the “wretched of the earth” living in those regions ravished by centuries of colonial domination and grinding poverty. The representatives who met at Bandung all shared the historical commonality of colonial domination and were determined for a “joint struggle against the forces of imperialism.” They saw the new emerging pacts during global Cold War like the Manila Pact, and the Baghdad Pact as conduits for major powers to exercise their influence into their newly gained sovereignty.¹⁰

Jawaharlal Nehru, one of the towering figures at the conference and who was looked upon as the leader of the “Third World” stated,

So far as I am concerned, it does not matter what war takes place: we will not take part in it unless we have to defend ourselves. If I join any of these big groups I lose my identity; I have no identity left, I have no view left....if all the world were to be divided up between these two big blocs what would be the result? The inevitable result would be war. Therefore every step that takes place in reducing that area in the world which may be called the “unaligned area” is a

⁹ Kux, *Estranged Democracies*, p. 447.

¹⁰ Vijay Prashad, *The Darker Nations: A People's History of the Third World* (New York: New Press, 2007).

dangerous step and leads to war. It reduces objectivity, that balance, that outlook which other countries without military might can perhaps exercise¹¹

The conference itself was instrumental in the further decolonization of countries and the formation the Non-Aligned Movement (NAM).

John Foster Dulles, Secretary of State during Eisenhower's presidency declared that neutralism was an "immoral and short sighted conception" and MacArthur reasoned that it would create imbalance in the current world order and might pull Japan, an ally of US, toward that sphere.¹² To check the influence of communism in the newly decolonized states and to keep an American presence, Dulles insisted on pacts, alliances and treaties. Eisenhower saw it as a "move toward the left among the neutral countries." In this tense political climate Dulles even proposed an idea of a "reverse Bandung conference, in which the Western oriented 'Third World' countries would have the upper hand."¹³ In the ensuing drama at Bandung, India was seen as a "great villain" and all the nation states, twenty nine countries, that met at Bandung, were found guilty of the "vice of nonalignment."¹⁴

In this geopolitical context, though the relations between United States and India seemed "estranged" on the surface during most of Cold War, it is rather intriguing to see

¹¹ Speech in the closed session of the Asian-African conference, Bandung, 22nd April 1955, quoted from Nehru, selected works, second series, vol. XXVIII, p. 108, cited in Westad, *Global Cold War*, p. 101.

¹² Vijay Prashad, *The Darker Nations: A People's History of the Third World* (New York: New Press, 2007); <http://www.bandungspirit.org/spip.php?article4> (accessed on March 11, 2011); for a scholarly account of United States and its reaction to the Bandung conference and the policy of non-alignment see H.W. Brands, *The Specter of Neutralism: The United States and the Emergence of the Third World, 1947-1960* (New York: Columbia University Press, 1989).

¹³ Odd A Westad, *The Global Cold War: Third World Interventions and the Making of Our Times* (Cambridge: Cambridge University Press, 2005), p. 103.

¹⁴ Gabriel Kolko, *Confronting the Third World: United States Foreign Policy, 1945-1980* (New York: Pantheon Books, 1988). 61-62.

underneath this “cold peace” the extensive role the United States played through different government institutions and agencies to modernize India and to establish this new nation state as a capitalist model and a bulwark against the communist model adopted by the Soviet Union and China. Since India was sandwiched between a number of newly decolonized Afro-Asian countries, the United States felt that it was imperative to stabilize and develop it along capitalist and democratic ideals so as to win the hearts and minds of millions of people in the Afro-Asian region. This is evident through the massive economic aid India received from the United States during the first two decades of India’s independence and the constant traffic of experts -- from science and technology to cultural, linguistic and economic fields--, between the “metropolis” and “periphery.”¹⁵

Technology and Modernization

The beginning of American efforts to modernize, a term that received traction only after WWII, newly decolonized regions can be traced to President Truman’s inaugural address delivered on January 20, 1949. In the Point IV of the inaugural address, he called on the United States “to embark on a bold new program for making the benefits of our scientific advances and industrial progress available for the improvement and growth of underdeveloped areas.”¹⁶ The timing of the Truman’s speech was a response to the emerging Cold War and the wave of decolonization that was altering the global

¹⁵ For a detailed analysis of modernization efforts by the United States in developing countries see George Rosen, *Western Economists and Eastern Societies: Agents of Change in South Asia, 1950-1970* (Baltimore: Johns Hopkins University Press, 1985); Michael E. Latham, *Modernization as Ideology: American Social Science and “Nation Building” in the Kennedy Era* (Chapel Hill: University of North Carolina Press, 2000); Nils Gilman, *Mandarins of the Future: Modernization Theory in Cold War America* (Baltimore: Johns Hopkins University Press, 2004); David C. Engerman, “West Meets East: The Center for International Studies and Indian Economic Development” in *Staging Growth: Modernization, Development, and the Global Cold War*, David C. Engerman, Nils Gilman, Mark H. Haefele, and Michael E. Latham, eds., (Amherst: University of Massachusetts Press, 2003), 199-223; Nicole Sackley, “Passage to Modernity: American Social Scientists, India, and the Pursuit of Development, 1945-1961,” Ph.D. Dissertation, Princeton University, 2004.

¹⁶ *Point Four: Cooperative Program for Aid in the Development of Economically Underdeveloped Areas* (Washington D.C., 1949), 95.

landscape. The fall of China to Chairman Mao in 1949, and the Korean War that ensued only hastened the need to provide structural solutions for leading the new nation states toward liberal capitalist directions to achieve “progress.”

For providing structural solutions a new breed of experts commonly referred to as “modernizers” emerged on the international scene. This group was composed of an eclectic mix of social scientists and economists who crossed the academy to take government positions to spearhead policies aimed at improving developing nations. One of the chief architects of modernization theory Walt Whitman Rostow, housed at the Center for International Studies (CENIS) at Massachusetts Institute of Technology, proposed a systematic formula for leading developing countries toward economic development. In his book *The Stages of Economic Growth: A Non-Communist Manifesto* he observed distinct stages of socio-economic progress – of how a society progresses from its tradition and passes through various stages before it attains maturity preconditions for take-off, the drive to maturity, and lastly the age of high mass consumption.¹⁷ Central to Rostow’s manifesto for the march of modernity into developing countries was the “importance of the rise of scientific thinking” and the humans competence to “manipulate the environment.”¹⁸ His writings became influential among native elites in developing regions who selectively appropriated the development discourse to articulate their own meanings to develop their country.

¹⁷ W.W. Rostow, *The Stages of Economic Growth: A Non-Communist Manifesto* (Cambridge, Eng.: University Press, 1960).

¹⁸ Michael Adas, Modernization Theory and American Revival of The Scientific and Technological Standards of Social Achievement and Human Worth,” in David C Engerman, Nils Gilman, Mark H. Haefele and Michael E. Latham, eds., *Staging Growth: Modernization, Development and the Global Cold War* (Amherst: University of Massachusetts Press, 2003), 35.

The modernizers in general, viewed all societies around the world to be in a continuum progressing toward a telos. At the end of this continuum was the United States which had already “arrived.” The newly decolonized states were seen to be at different points or ‘stages’ along the path. Given the time and economic and technical assistance – a key variable in the modernization project; and planning, the modernizers believed that any region of the globe could become “developed.” For offering structural solutions to endemic problems, the modernizers looked at their own countries’ history and extract solutions for overcoming the hurdles developing countries were facing. For example, the modernizers often invoked the model of the Tennessee Valley Authority (TVA) to show how a poor region in the US was converted into a flourishing growth area, emphasizing that it could form a prototype for instituting development projects in poor regions across the globe. “TVA presented itself as a technical solution to social, political, and economic problems and hence a counter model to Communism.”¹⁹ The promise offered by science and technology to help achieve modernity attracted the leaders of developing countries. There was a surge from western trained postcolonial elite India who embraced science and technology as instruments for building an independent national agenda.

Seen through the grid of technology and modernization -- early nuclear cooperation, the origin and development of the Indian space program through NASA, artificial rainmaking experiments, population control, hybrid seeds and green revolution experiments funded by the American private and academic foundations -- all of these technological projects during the fifties and sixties can be seen as a part of the renewed attempt by the U.S. to develop India and to make it a laboratory to pull the Indian elite

¹⁹ Nils Gilman, *Mandarins of the Future*, p. 38-40.

into the Western sphere of influence. India was locked into a global strategic position and the United States had a vested interest in keeping it there.

India's humiliating defeat in the border war with China in 1962 briefly brought the United States and India closer together. The defeat by China was a "Sputnik shock" for the Indians that led to a rapid rise in defense budgets. Renewed importance was given to science and technology for defense purposes. John F. Kennedy's administration made use of this opportunity to promote India as a democratic counterweight to China.

Kennedy's policy toward developing countries, India in particular, showed a striking difference compared to previous administrations. While Dulles divided countries into pro and anti communists, Kennedy and his advisers were sensitive to the needs of new postcolonial states and gave room for the expression of independent foreign policies by different countries in the developing world. He aimed to stall the expanding communist ideology in Afro-Asian countries through economic aid and modernization. He believed that economic stability would bring prosperity and political stability which in turn would be a bulwark against expanding communism. However, ongoing distrust of India's neutrality colored Kennedy's perception of the country and stifled his innovative approaches to improve bilateral relations. Indo-American relations during Lyndon Baines Johnson's administration were anything but cordial. The Indo-Pakistan war in 1965, India's public criticism of Johnson's policy in Vietnam, and Johnson's use of Public Law 480 -- through which India received food grains, to force India's support of US policy in Vietnam, all increased tensions. This short tether policy during a time of severe famine in 1965-67 eroded years of good will and left scars. President Nixon's decision to support Pakistan during a war between India and Pakistan over the creation of Bangladesh

(formerly East Pakistan) in 1971 brought US-India relations to its nadir. Nixon cancelled all bilateral economic aid to India and Indira Gandhi openly sought friendly relations with Soviet Union.²⁰

Viewed through this geopolitical contextual grid, significant US-India cooperative endeavors in space science and technology were not uniform but ebbed and flowed and were constantly shaped by this larger bilateral foreign policy framework. Significant punctuation points that altered, for good and for worse, US-India relations in space were: India's border war with China - 1962; the Chinese nuclear test - 1964; Indo-Pakistan war of 1965, the Chinese launch of a satellite 1970; the Indo-Pakistan War - 1971; India's first Peaceful Nuclear Explosion (PNE) - 1974; the successful orbiting of India's satellite Rohini through an indigenously built Satellite Launch Vehicle (SLV-3) in 1980; the start of the Integrated Guided Missile Development program (IGMDP) in India -1983; the impact of the Missile Technology Control Regime (MTCR) - 1987; the Pokhran II nuclear weapons tests - 1998 and the closer diplomatic relations that ensued after the 9/11 terrorists attacks on the United States. This dissertation mainly focuses on the early stages of cooperation (1955-1976) -- from the establishment of optical tracking of artificial satellites through the Smithsonian Institution during the International Geophysical Year (IGY) to the execution of a one-year experimental television project in 1975-1976. The two-decade timeline marks the beginning and waning of the first phase

²⁰ Also in the early seventies there was a strong feeling that aid was not supporting modernization efforts in India. Daniel Patrick Moynihan, who was sent to India as an ambassador to improve relations with Indira Gandhi after the 1971 war stated that "it is no longer possible to believe that the aid programs of the 1960s are workable. It costs too much to give India money. For one thing they hate you for it; for another we do not have the economic or political resources to mount a significant aid program." Daniel P. Moynihan and Steven R. Weisman, *Daniel Patrick Moynihan: A Portrait in Letters of an American Visionary* (New York: Public Affairs, 2010), p. 326.

of close interaction between United States and India in the realms of space science and technology.

Vikram A. Sarabhai and Homi J. Bhabha

The origin of the Indian space story often begins with the visionary scientist and technocrat Vikram Sarabhai, who is credited as being the father of India's space program. But the early phase owes as much to the pioneering efforts of Homi Bhabha who was instrumental in the establishment of scientific institutions for the growth of science and technology in modern India.²¹ By the late fifties, when initiatives were taken to pursue space research at a systematic level in India using scientific balloons and miniature rockets, Bhabha had already established the scientific ethos and the rationale for the pursuit of cutting edge technologies in the nuclear and space domains, and had launched a major nuclear program.²² The duo, however, were not new to the field of space sciences, they had established their niche in cosmic ray physics even before they thought about huge scientific projects for the emerging nation state.²³ In particular, Sarabhai was

²¹ For a recent biographical work on Homi J. Bhabha see Indira Chowdhury and Ananya Dasgupta, *A Masterful Spirit: Homi J. Bhabha, 1909-1966* (New Delhi: Penguin Books India, 2010).

²² For an excellent history of India's nuclear program see, Itty Abraham, *The Making of the Indian Atomic Bomb: Science, Secrecy and the Postcolonial State* (London: Zed Books, 1998). George Perkovich, *India's Nuclear Bomb: The Impact on Global Proliferation* (Berkeley: University of California Press, 1999).

²³ See for instance Homi J. Bhabha, and W. Heitler, "The Passage of Fast Electrons and Theory of Cosmic Ray Showers," *Proceedings of the Royal Society*, 159 A, (1937); Homi J. Bhabha, "On Penetrating Component of Cosmic Radiation," *Proceedings of the Royal Society*, 164 A, (1938). Vikram Sarabhai worked in the field of cosmic ray variations and set up a group which was undoubtedly the best in this field and which achieved recognition in international science. He was for some years secretary of the internationally instituted Sub-committee on cosmic ray intensity variations and was also a member of the cosmic ray commission of the international union of pure and applied physics. While Tata Institute of Fundamental Research was the cradle of the Indian Atomic energy program, Vikram Sarabhai made the PRL the cradle of the Indian space program. His first scientific contribution, "Time Distribution of Cosmic Rays, was published in the Proceedings of the Indian Academy of Science in 1942. During this period at Cambridge he also carried out an accurate measurement of the cross section for the photo fission of ^{238}U by 6.2 mev r-rays obtained from the ^{19}F (p, r) reaction. This work also formed a part of his PhD thesis, see S.P. Pandya, "The Physicist" in *Vikram Sarabhai: The Man and the Vision*, Padmanabh K. Joshi ed., (New Delhi: Mapin, 1992), pp. 52-57.

aware of the research opportunities, made possible by space technology, to study the upper atmosphere. Together they initiated early interactions with NASA for possible cooperative space projects.

Vikram Ambala Sarabhai was born in Ahmedabad, India on 12 August, 1919 to a wealthy family of industrialists.²⁴ After finishing his early education in Ahmedabad he moved to St. John's College, Cambridge, UK in 1937 where he took his Tripos with Physics and Mathematics in 1940 and continued his postgraduate work in nuclear physics. He returned to India after the outbreak of WWII and continued his professional training as a research scholar under Nobel Laureate C.V. Raman at the Indian Institute of Science (IISC) Bangalore. It was at IISC that he nurtured a friendship with Homi Bhabha who was also researching on cosmic rays, and who established a research unit for this purpose at IISC.²⁵

Sarabhai returned to Cambridge after the war in 1945 and his extensive fieldwork carried out in Bangalore and Agharwat in the Kashmir region of the Himalayas enabled him to receive his Ph.D in 1947 for his doctoral thesis, *Cosmic Ray Investigation in Tropical Latitudes*. After getting his degree he soon returned to a new India that became independent in 1947 after centuries of British colonial rule. Jawaharlal Nehru became the first prime minister of India. Trained in Harrow and Cambridge, Nehru believed science to be a panacea for the innumerable problems faced by humanity. As he put it, "it is science *alone* that can solve the problem of hunger and poverty, of insanitation and illiteracy, of superstition and deadening custom and tradition, of vast resources running to

²⁴ For a recent scholarly treatment on his biography, see Amrita Shah, *Vikram Sarabhai: A Life* (New Delhi: Penguin, 2007).

²⁵ For a detailed account of Bhabha's work on Cosmic Rays in Bangalore see Jahnavi Phalkey, "Science, State-Formation and Development: The Organization of Nuclear Research in India, 1938-1959," Ph.D. dissertation, Georgia Institute of Technology, 2007, pp. 157-161.

waste of a rich country inhabited by starving people. Who indeed can afford to ignore science today? At every turn we have to seek its aid. The future belongs to science and to those who make friends with science.”²⁶ There was an air of optimism and vibrancy, and the trio –Nehru, Bhabha and Sarabhai -- with patronage from the government and private industrial enterprises like the Tata trust -- the Medici’s of India, and Sarabhai’s own family business conglomerate, would become potent actors to wield science and technology to cement the new nation-state.²⁷

Vikram Sarabhai started a laboratory for the study of cosmic rays in Ahmedabad, which was later institutionalized by the setting up of the Physical Research Laboratory (PRL) in 1954.²⁸ Thanks to the business enterprise his family had established, he became in Thomas Hughes’ phrase, a heterogeneous engineer with a multitude of portfolios.²⁹ Popular writings portray him as an institution builder, a visionary, a pragmatist and a Gandhian. Sarabhai viewed the development of a nation to be intimately linked with the understanding and application of science and technology by its people. He did not believe in direct development through the application of sophisticated technologies, but rather in understanding the science behind how technology functions. He saw the new emerging

²⁶ Gyan Prakash, *Another Reason: Science and the Imagination of Modern India* (Princeton: Princeton University Press, 1999), p. 196.

²⁷ For more on the role of science and technology in national identity see Carol E. Harrison and Ann Johnson, “Introduction: Science and National Identity,” *Osiris* 24 (2009): 1-14.

²⁸ At the recommendation of Vikram Sarabhai, the laboratory was founded following an agreement between the Ahmedabad Education Society and the Karmakshetra Educational Foundation in November 1947, see Government of India, *25 Years of PRL* (Ahmedabad: Physical Research Laboratory, undated), p. 4.

²⁹ He established the Ahmedabad textile Industry’s Research Association (ATIRA), started the Physical Research Laboratory (PRL) at Ahmadabad, took over the management of Sarabhai Chemicals in 1950, established Suhrid Geigy Limited in 1955, assumed the management of Swastik Oil Mills Limited, founded the Ahmadabad Management Association in 1957, and set up Sarabhai Merck Limited in 1958, also took over Standard Pharmaceuticals in Calcutta, established Sarabhai Research Centre in Baroda and the operations Research Group (ORG) in 1960, was also the prime mover behind establishing the Indian Institute of Management (IIM) at Ahmedabad, see Raj, *Reach for the Stars*, pp. 6-7 and Shah, *Vikram Sarabhai*, chapter 3.

field of space sciences not purely as basic scientific research -- science for pure knowledge's sake, but as obligatory passage points for embarking on development programs. He stated that "...pursuit of cosmic rays and space research does not require an apology in a developing nation provided the activities are within a total scheme of priorities in the allocation of national resources." He viewed engaging with pure sciences as a logical step toward strengthening the "organization and conduct of education," and creating infrastructural facilities for the development of electronics and chemicals. He further stated that "I am actively interested in the application of science for the improvement of agricultural productivity and in the implications of science to society and problems of security."³⁰

Vikram Sarabhai was also known in international circles as an apostle for world peace and disarmament. He was a member of Continuing Committee of Pugwash, and participated in Pugwash Conferences on Science and World Affairs and set up the Indian Pugwash Society. He was also interested in integrating India with the global community. His familiarity and high esteem at international meetings was recognized and he was elected president of the 14th general Conference of the International Atomic Energy Agency (IAEA) in 1970.³¹ The sense of isolation that India experienced under colonial rule served as a major impetus for building a domestic program, to engage with scientific institutions around the world as an equal partner, and to create avenues for technology and idea sharing.

³⁰ Kamla Choudhary, *Vikram Sarabhai: Science Policy and National Development* (Delhi: Macmillan 1974), p. 24.

³¹ Noble laureate Glenn T. Seaborg wrote his obituary praising his international stature and scientific accomplishments, "Vikram A. Sarabhai: In Memoriam," *The Bulletin of Atomic Scientist* 28, no. 4 (April 1972), p. 48.

Sarabhai, when speaking for the development of India, argued “what applies to the economy of India applies to the economy of most of the countries in the Indian Ocean region. Space meteorology, which permits the acquisition of valuable data from satellites as well as with the use of sounding rockets, has, therefore, a special significance for us.” His international position is very important for looking at US-India relations in space because in the late 1960s Sarabhai became the scientific Chairman of the UN Committee on Peaceful Uses of Outer Space, and so became a vector, as it were, to publicize the benefits of space for the newly formed developing nation states. At the same time, while advocating for space sciences, he was vocal against the needless craving for prestige that might accrue when a developing nation embarked on a space program.

U.S. officials were captivated by the unusual combination of industrialist and physicist in one man. His participation in international conferences, his accomplishments in basic scientific research, his visiting faculty status at MIT, the list of committees, commissions and boards that he was a member of impressed the American embassy officials in India who wrote long reports to the U.S. State Department of his activities. These qualities played a crucial part when NASA was spreading its wings across the developing regions – here was a member of a native elite who could be a suitable ambassador for NASA’s peaceful programs in developing countries and not just in the region but across the world.

Understanding the web of transnational relationship

For the newly independent country, eagerly desiring for leapfrogging into modernity, India was locked into transnational networks of knowledge circulation. To build a new modern nation state underpinned by technological strength required constant flow of knowledge and technology from other countries. As modernization became highly entrenched, the elites began to realize that its something they cannot do it on their own, therefore India was forced to do some strategic alliances with various western powers, above all the US, the leading technological power in the globe. The circulation of knowledge and technology that we see here is out of compulsion and is something not easily visible to the local. How do we understand the interdependence at the technological level? Classically, scholars have used George Basalla's heuristic model explained in the "Spread of Western Science" for interrogating knowledge and technology flow.³² Though a lot of criticisms have been piled on the diffusion model, it forms a reference point for initiating a dialogue on circulation of knowledge across nation states. In the article Basalla describes the diffusion of Western science from the "center" – Western Europe, to the "periphery" – rest of the world; happening through three phases – exploration, dependence and culminating in the creation an independent scientific tradition or culture. Rather than from being hegemonic – from the "center" to "periphery," what we see in reality is a genuine circulation of knowledge and interdependence. To understand the complex web of transnational relations one has to move beyond Basalla's model to see the contours. In a recent article on the US-European

³² George Basalla, "The Spread of Western Science", *Science*, vol. 156 (May 1967): 611-622. There is no dearth of scholarly interrogation of Basalla's diffusion model, for an excellent critique see, Deepak Kumar, *Science and the Raj* (Delhi: Oxford University Press, 1995), Kapil Raj, *Relocating Modern Science: Circulation and the Construction of Knowledge in South Asia and Europe, 1650-1900* (Houndmills, Basingstoke, Hampshire, England: Palgrave Macmillan, 2007), Arnold, David. *Science, Technology and Medicine in Colonial India* (New York: Cambridge University Press, 2000).

scientific relations, John Krige explains that, though the relations were embedded in an asymmetric field of force – United States as “center” and Europe as “periphery,” the European scientific community were not denied agency.³³ They were “characterized as ‘selectively appropriating’ or even completely rejecting values, material practices and research agendas to accommodate the stamina of local cultures.” In a similar vein Indian elite with all its divisions, was a highly trained articulate elite with their own agenda. They were determined to leave their footprint on how the space program would evolve in India. The tensions behind leaving its footprint and the determination of the US to leave its footprint is part of my story. This dynamic relation is best captured by the metaphor of “coproduction,” a term that has received traction among diplomatic historians, historians of technology and science studies. It is a valuable way of emphasizing the agency of both parties and the non-linear circulation of ideas and people back also to the United States. The ambivalence implied by this dyadic relation opens further room for investigating transnational networks and knowledge flows in high-technology – space and also nuclear; between “metropolis” and “periphery” and between “periphery” and “periphery.”

John Krige extended this term in his book *American Hegemony: Postwar Reconstruction of Europe*, to characterize the emergence of the American empire as a “negotiated outcome of a complex process in which European partners selectively appropriated and adapted features of the U.S. agenda and ambitions for the Continent and made them their own.” Without the use of force, the United States levered its scientific technological preeminence, through the agency of a “transnational elite” to convince partners in Europe to align with the United States. Rather than being passive receivers, as

³³ John Krige, "Building the Arsenal of Knowledge," *Centauros* 52, no. 4 (2010): 280-296. For an analysis of the center and periphery model in Europe see Gavroglu, K. et al., "Science and Technology in the European Periphery. Historiographical Reflections," *History of Science*, 46 (2008): 153-175.

in consensual hegemony, the “United States gave Europeans room to leave their imprint on the hegemonic regime and this implies that empire building is a fluid process.”³⁴

Recently two historians of science and technology, Jennifer Von Vleck and Zuoyue Wang have appropriated this metaphor for their case studies on US aviation assistance to Afghanistan and for analyzing Chinese American scientists.³⁵ Science studies scholars have used the term coproduction to denote the dynamic reciprocal evolution of science and politics. Sheila Jasanoff in her book *States of Knowledge: The Co-Production of Science and Social Order*, defines it as the “simultaneous production of knowledge and social order.”³⁶ Seeing the increased plasticity of the term and its salience, I have appropriated it for framing the Indian space program as well. I use this metaphor to denote the mutual shaping of the Indian space program catered toward socio-economic benefits by native elite and foreign experts. What a space program should be in developing countries was contested during the course of Indian elites’ engagement with the evolving space technology. US experts wanted to channel the space program to address core issues of a developing nation state – population, literacy, national cohesion, agricultural improvement, rural upliftment, etc. The Indian space establishment however wanted to develop a full-fledged space program (a fleet of application satellites and launch vehicles) to cater to the socio-economic needs of a developing nation and also the strategic needs of a sovereign nation state. This tension gets manifested in the evolution

³⁴ John Krige, *American Hegemony and the Postwar Reconstruction of Science in Europe* (Cambridge, Mass: MIT Press, 2006), pp. 4-6.

³⁵ Historian Zuoyue Wang using the pioneering work of John Krige, has extended the transnational approach to cold war science to study China’s engagement with Cold War science. Zuoyue Wang. “Transnational Science During the Cold War: The Case of Chinese/American Scientists.” *Isis* 101, no. 2 (2010): 367-77. Jennifer Van Vleck, “An airline at the crossroads of the world: Ariana Afghan Airlines, modernization, and the global Cold War, *History and Technology* 25, no. 1 (March 2009): 3-24.

³⁶ Sheila Jasanoff, *States of Knowledge: The Co-production of Science and the Social Order* (London: Routledge, 2006).

of the Indian space program. Secondly, India offered a virgin ground for testing sophisticated technologies – the satellite TV is a case in point. The planning and execution of the experiment offered vital data for NASA and business corporations to learn what shape a space program should take in other developing countries.

Transnational Networks and Knowledge Flows

This dissertation, while narrating the evolution of the Indian space program through the grid of US-India relations opens room to chart knowledge flows in science and technology during Cold War. While there is no dearth of analysis of US-India political relations, scholars are beginning to unravel the extensive engagement with India in the field of science and technology. The volume of aid in science and technology that India received during the fifties and sixties is quite startling. US ambassador to India Chester Bowles (1953-55; 1963-1969) in an article in *Foreign Affairs* states that:

The United States has helped rebuild and modernize India's railroads, contributed 60 percent of the capital for India's power development, helped build and staff eight agricultural universities, provided nearly 40 million tons of food grains, printed millions of books for Indian schools, published four excellent magazines to help Indians better understand America, provided thousands of American technicians and made it possible for thousands of Indians to go to America for training and advanced education. The size of the US Peace Corps in India has been double that in any other nation.³⁷

Key Indian actors in scientific and technological establishments desired and sought technical aid from United States. It was only when it was denied that the Indian elites turned to the Soviet Union or other partners in the international arena. The case studies dealt with in the dissertation also show that the dynamic knowledge flow was not

³⁷ Chester Bowles, "America and Russia in India," *Foreign Affairs* 49, no. 4 (July, 1971): 636-651.

just between “center” to “periphery” – USA and into India; but also between “periphery” and “periphery.” By engaging with India, which the United States treated as a laboratory, experts were exposed to the realities of a developing country; their experiences in India, coupled with data collected through American foundations, educational institutions, the Peace Corps, the American Embassy and Consulates, and others, on disparate topics directly fed the “arsenal of knowledge.”³⁸ The development of the Indian space story clearly shows the hidden transnational movements of systems and software and experts during the Cold War.

Dissertation Chapters

The case studies dealt here constitute the ‘civilian’ side of a space program along the three classic axis – science, application, and launchers. As we move from science to launchers, we draw closer to the sensitivity of the technology. Just as the nuclear program has dual use – production of energy and for weaponry; the space program also acquires dual use capability as it moves from science to launchers -- commercial and military interests.

Before we delve into the chapters, it is important to distinguish between cooperation and collaboration here because most of the transnational knowledge and technology flow was in the realms of cooperation. In collaboration, rather than pursuing an independent course of action, different partners are inclined to pool their resources and closely work together to achieve their goals. However, collaboration is not the norm among competing partners who are pursuing scientific and technological knowledge,

³⁸ John Krige, "Building the Arsenal of Knowledge," *Centaurus* 52, no. 4 (2010): 280-296. I'm using this phrase to include not only knowledge related to science and technology but also to humanities and social sciences.

often it is a “negotiated outcome,” wherein, “stakeholders balance the benefits of tapping into the resources that others have to offer against the costs of sharing what they have with their competitors.” Cooperation on the other hand does not involve a lot of investment in resources that collaboration demands. Often cooperation is sought, through formal conventions and procedures, for collecting massive amounts of data from different geographical regions. In cooperation transnational flow of sensitive technology is kept at a minimal level. Gathering data about the properties of ionosphere on the geomagnetic equator is a clear case of cooperation wherein the technology exchanges are kept minimal but the acquired data is made public for broader scientific community.³⁹

Baker Nunn and Nike Apache

At the heart of the first chapter are two technological systems: a Baker Nunn camera for photographing artificial satellites and sounding rockets for studying various atmospheric phenomena. Both the systems were loaned to India by two different organizations – the Smithsonian Institution and the National Aeronautics and Space Administration (NASA), under the purview of the United States State Department. Given the traffic of experts between India and the United States during the early twentieth century for jointly studying the scientific properties of the atmosphere, it would be misleading to define a precise date and time to mark the beginning of collaborative endeavors. However, based on the level and nature of interaction, and the circulation of technology from the United States into India, one can temporally mark the beginning to the International Geophysical Year (IGY – July 1957-December 1958). Many scientific institutions in India, through close coordination with various committees formed during IGY, systematically collaborated in a number of scientific investigations. Among the

³⁹ John Krige, “Collaboration” in G. Azoulay and D. Pestre, eds, *C'est l'Espace!* (Paris: Gallimard, 2011).

many programs that were planned and executed, the tracking of artificial satellites using sophisticated equipment sponsored by the United States clearly stands out in terms of the level of technology shared and the active participation of experts. Two scientific institutions, the Smithsonian Astrophysical Observatory, based in Harvard, Massachusetts, USA and Uttar Pradesh State Observatory (UPSO), Nainital, India, began negotiations in the mid 1950s for operating a highly advanced telescopic camera called Baker Nunn. Experts from the United States migrated to India to collaborate with Indian counterparts for finding a location to establish an observatory for tracking satellites. However, the planning and operation of the observatory was not a smooth endeavor. The technology did not diffuse nor were the Indians were passive receivers. Echoes of Bandung reverberated in the foothills of the Himalayas during the global Cold War. With the onset of tracking by astronomers the scene shifted from the icy north, to the sultry south where a team of space scientists in collaboration with NASA located a place on the western seacoast to establish an international sounding rocket range. A nascent space program was kick started with the orange streak of sodium vapor clouds in the tropical skies. With a nuclear program (civilian and scientific) in parallel, which steadily gained momentum since India's independence, India glowed, for a short time, as a scientific and technological leader among Afro-Asian states. The glory, however, was dispelled by the Chinese nuclear test explosion leaving the space and nuclear program to etch a Janus face: Gandhi and *Yama* (Lord of Death in Sanskrit language) -- A space program for rural welfare and a credible nuclear deterrent for annihilation.

Scout and SLV-3

Chronologically moving ahead, the third chapter revolves around a satellite launch vehicle (SLV-3). The initial planning for developing a rocket began in the mid 1960s soon after the Chinese nuclear test. Bhabha and Sarabhai contacted NASA for transferring Scout rocket technology to build a similar rocket in India. Being a dual use technology, capable of launching a satellite as well as delivering a bomb, the technology was refused. However, Scout being an all solid propelled rocket the Indian experts felt confident that they could attempt and succeed by modeling their first rocket on Scout.

The momentum for building a rocket began soon after the 1971 Indo-Pakistan war and the sudden death of Vikram Sarabhai. The scene progressively shifts from Thumba, located on the Western sea coast to Sriharikota on the Eastern sea coast. A new breed of western trained engineers and technologists began to head various units in the space establishment. To build the system, experts from India shopped for ideas and bought subsystems in the US, Japan, France, Germany and Australia. This chapter offers a window to capture the extent of transnational traffic of ideas, systems, software and experts. It also discusses the extent of “periphery-periphery” technological collaboration, hitherto not given much attention in space history.

ATS-6 and Satellite Instructional Television Experiment

I began my dissertation by first writing about a highly advanced, state of the art, communication satellite called the Application Technology Satellite (ATS-6). The satellite was used to broadcast educational television programs directly to television sets placed in different rural clusters. The locus of action was Ahmadabad, in north-west India, where a team of experts orchestrated and designed augmented television sets, antennas and placed them in 2200 villages. Experts from Stanford, MIT, NASA, and

private foundations like Ford and Rockefeller, all contributed during planning, execution and evaluation stages. Coming soon after the Apollo moon landings this was an important project for NASA to “broadcast” the benefits of space technology for the common people.

A Note on Archives

Anyone attempting to tell the story of India’s space program cannot do justice to the topic by merely relying on annual reports, internal publications periodically produced by the Department of Space and by oral histories. The history is intrinsically transnational. A variety of sources in different countries have been consulted to write this dissertation. The NASA History Office located at the NASA Headquarters Washington D.C. provided some background material and technical details about United States cooperation with India. Declassified State Department documents from the National Archives II, College Park, MD, and the Lyndon Baines Johnson Presidential Library, Austin, Texas, provided correspondences and briefs between agencies and official letters by key personnel. News clippings from the Library of Congress came in handy to fill the gaps. Apart from these American sources, documents were also collected in India. Collecting documents and reports in India was challenging. The Indian Space Research Organization (ISRO) has not established a formal archival facility so far, and the documents – correspondence, reports, minutes etc.--, are trashed, burnt or, misplaced. However, a few scientists, engineers and government officials who were involved in the project shared their personal collections and the sources that I acquired are mainly through this channel. Oral histories were also conducted extensively with key actors who were concerned with the project.

Chapter II

India Enters the Space Age: From Optical Tracking of Satellites to Sounding and Lighting the Tropical Space

This chapter is an historical account of India's relations with the United States in the field of space sciences, and narrates the progressive development of various institutions by the indigenous elite to establish a space program in India. The need for the synoptic investigation of geophysical phenomena in different regions across the globe during the International Geophysical Year (IGY) created the milieu for initiating space science collaboration with India. One of the scientific investigations during IGY was tracking artificial satellites. For this purpose the Smithsonian Astrophysical Observatory (SAO), located in Harvard, Massachusetts, loaned a highly specialized Baker Nunn camera, ancillary equipment, and expertise to Uttar Pradesh State Observatory (UPSO), in Naini Tal, India. It was one of the world's twelve observatories that filled an important gap between Iran and Japan in the world network of tracking stations. Through these stations, the approximate positions of satellites (both Soviet Union and American) were obtained. The camera was the first 'large' technological system to enter India in the realm of space science and technology from the United States. Though it was a small scale joint collaboration, the early UPSO-SAO nexus, would indicate the pattern of collaborative space endeavors that would soon emerge in the Indian subcontinent. From optical tracking in the foothills of the Himalayas in Northern India, space research would move to a tropical Southern region where, with the help of the National Aeronautics and Space Administration (NASA), India, through a nascent space establishment—

INCOSPAR attached to Department of Atomic Energy; would eventually embark on a space program by launching sounding rockets. In both cases, India received technological aid and American experts traveled to India for site selection and for planning and establishing facilities. Progressively the facilities that began for space sciences were expanded for the incremental development of a full-fledged space program – application satellites and launch vehicles. The chapter ends with the sudden death of Vikram Sarabhai in 1971 and the institutionalization and reorganization of a space program under a separate Department of Space (DOS) directly under the Government of India in 1972. The direction the Indian space program received under Vikram Sarabhai and the close cooperation that came from United States, mainly through NASA -- both technical and managerial and the geopolitical realities, and domestic political and socio-economic demands shaped the future trajectory of India's space ambitions.

Origins of the IGY and Indian Contributions

The International Geophysical Year (July 1, 1957- December 31, 58) that succeeded two International Polar Years (1882-83 and 1932-33) was an important event that galvanized disparate scientific communities in different parts of the world, sixty seven countries in total, to study the physical environment of planet Earth (geophysical) and astronomical phenomena during the global Cold War. Recently, its fiftieth anniversary was celebrated or remembered in many countries. The Smithsonian Institution, one of the premier institutions in the world, organized a seminar series by inviting scholars to present papers and also brought out a book entitled *Globalizing Polar Science* at the 2010 History of Science Society (HSS) Annual meeting in Montreal, Canada, in commemoration of that. “Collective memories” aside, it is very clear with

hindsight, that the IGY was not only a seminal event for integrating scientific findings around the world for studying geophysical phenomenon on a truly global scale but it also laid the foundation for organizing civilian space programs in different countries including India.

Sixty one years ago, the young Van Allen, just 36 years of age, took the initiative of organizing a dinner party at his residence when Sidney Chapman, almost twice his age, was visiting the Applied Physics Laboratory at John Hopkins University in Baltimore. The event on 5 April 1950 was more than a budding physicist exchanging pleasantries and catching up with a world renowned geophysicist. Van Allen also took the opportunity and invited other geophysicists, Lloyd Berkner, James Wallace Joyce, Ernest Vestine, and S. Fred Singer to join them. It was at this dinner party while enjoying a dessert – a chocolate layer cake baked by Abigail Van Allen-- that Chapman and Berkner developed the idea of another International Polar Year (IPY) for 1957-58. An IPY, they thought, would end the “frustration of geophysicists” who wanted to understand the geophysics and astronomical phenomena of the planet in totality by investigating data collected simultaneously from many observatories. The time period was chosen because the solar activity would be at its maximum and also the Earth would be subjected to a lot of external influences.⁴⁰

From the living room of Van Allen’s residence the idea was given more shape at various conferences and it was finally proposed at the International Council of Scientific Unions (ICSU) which provided the administrative set up for this program in cooperation

⁴⁰ Abigail Foerstner, *James Van Allen: The First Eight Billion Miles* (Iowa City: University of Iowa Press, 2007); Lloyd Viel Berkner, “The International Geophysical Year, 1957-1958: A Pattern for International Cooperation in Research,” *Proceedings of the American Philosophical Society* 101, no. 2 (April 19, 1957): 159-163.

with World Meteorological Organization (WMO) and other scientific bodies. As some scientists at the council preferred a global study than just the Polar Regions, Chapman readily agreed to a global geophysics study, and renamed the program as the IGY. Patronage for such a mammoth endeavor came from Union Radio-Scientifique Internationale, the International Union of Geodesy and Geophysics, the International Astronomical Union and scientific members of ICSU. The whole program was institutionalized under a special Committee called Comité Spécial de l'Année Géophysique Internationale (CSAGI) and it took responsibility for organizing periodic regional and annual meetings -- Brussels 1953; Rome 1954; Brussels 1955, Barcelona 1956; Washington 1957, Moscow 1958, mainly for planning and organizing the event.⁴¹

At the initial meeting in Brussels, the CSAGI invited other nations to participate in the global endeavor through the establishment of observation stations in their respective countries. Every country that participated in the IGY had to establish its own National Committee. All the scientists and research organizations and government agencies, that wanted to participate in the IGY were channeled through their National Committees. The United States participated through the US National Committee (USNC) for the IGY. A total of 14 fields of investigations were chosen for the IGY and one of them was the launching of scientific satellites. Scientists from countries directly and indirectly using a variety of instruments mounted on ships, rockets, airplanes and balloons, produced large amounts of data for extending the knowledge of our planet and also toward safeguarding it. No region of the globe was untouched. All the data collected in participating countries were sent to IGY World Data Centers. The observation program

⁴¹ Sydney Chapman, "International cooperation and the IGY," *Bulletin of Atomic Scientists* 16, no. 5 (May 1960):173-178.

involved the establishment of special astronomical observatories in different geographic regions to look and study artificial satellites.⁴²

Though the IGY was initially planned for just 18 months, the program however, due to Soviet recommendation, and the overall enthusiasm shown by scientists, was extended beyond 1958 as the International Geophysical Cooperation (IGC). CSAGI was replaced by International Geophysical Committee to further geophysical research started during the IGY. The International Year of the Quiet Sun (IQSY) – (January 1, 1964 – December 31, 1965) was chosen by the committee as the next logical step after the IGY. The IQSY was a period of minimum solar activity and many investigations conducted during this period would complement the studies undertaken during the IGY. The IQSY was given the support of the United Nations. Scientists from 71 countries, India being one of them, participated in observations from 300 geographically distributed sites. The wonderful way the whole program evolved and the enthusiasm shown by lot of scientists led to other international programs – the Upper Mantle Project, the International Indian Ocean Expedition (IIOE), the International Years of the Active Sun (IASY), the International Magnetosphere Study (IMS).

The IGY brought many Indian scientists and institutions, old and new, together for the common cause of understanding the geophysics of the planet. It provided the

⁴² Scientific and national security interests drove the International Geophysical Year. The atomic age, in essence, formed the backdrop/grid on which basic scientific research on geophysical properties of earth was studied. The scientific content of the investigations was actually formed inside the U.S. Research and Development Board that was created to mobilize science after the end of WWII. The scientist and technocrat, Vannevar Bush led the board and he chose another scientist Lloyd Berkner to act as executive secretary. The noted British Geophysicist Sidney Chapman offered expert advice to the board. For a general history of IGY see Fae L. Korsmo, "The Genesis of the International Geophysical Year," *Physics Today* (July 2007): 1312-1316; Rip Bulkley, *The Sputniks Crisis and Early United States Space Policy* (Bloomington: Indiana University Press, 1991) and also Allan Needell, *Science, Cold War and the American State: Lloyd V. Berkner and the Balance of Professional Ideals* (Amsterdam: Harwood Academic Publishers, 2000).

opportunity for many Indian scientists to cross the threshold from the national to the international scene. For participation in IGY an Indian National Committee was formed in 1955 with renowned scientist Kariamanikkam Srinivasa Krishnan as President and Ashesh Prasad Mitra as Secretary. K.S. Krishnan was then acting as the Director of the National Physical Laboratory, (NPL -- 1947-1961) in New Delhi, and he also acted as the Vice Present of ICSU (1955-58) and like Vikram Sarabhai, he was the student of Nobel laureate C.V. Raman (*Raman Effect*). A.P. Mitra was the student of S.K. Mitra, the doyen of ionospheric research in India and who also participated in the IPY (1932-33). A.P. Mitra would contribute extensively during the IGY in upper atmospheric research and also during the IQSY. Even during the early stages, as early as 1953, representatives from India – Sarabhai from PRL and T.V. Ramamurthy from NPL -- were sent to the CSAGI planning meetings.⁴³

According to A.P. Mitra the IGY was a “poor man’s program,” by that he meant the scientific and technological requirements for conducting geophysical investigation did not demand a high degree of sophistication. India could participate and contribute with its existing infrastructure.⁴⁴ A plethora of geophysical measurements in the field of glaciology, meteorology, oceanography, seismology, geomagnetism, and cosmic rays was planned and executed during the IGY in India. The studies ranged from cloud cover studies in different cities, daily variations of magnetic elements in the geomagnetic equator, aurora and air glow measurements, ionospheric data for radio propagation, the variation of cosmic rays at different locations, solar activity, oceanography, seismology,

⁴³ For a scholarly treatment of India’s participation in IGY see S. Reddy, "India's Forays into Space." *International Studies* 45, no. 3 (2008): 215-245.

⁴⁴ Rajesh Kochhar, “Science as a Symbol of New Nationhood: India and the International Geophysical Year 1957-58,” *Current Science* 94, no. 6, (25 March 2008): 813-816.

glaciology, meteorology and latitudes and longitudes.⁴⁵ The Indian Meteorological Department, Kodaikanal Observatory, Physical Research Laboratory, Survey of India, All India Radio, Universities and few other scientific institutions were involved in executing the experiments. Sarabhai's contribution to cosmic ray studies – establishing monitoring stations, equipped with narrow-angle telescopes, in Kodaikanal, Trivandrum (now Thiruvananthapuram) and Gulmarg, for detecting cosmic rays from different directions --was also extended to become part of the Indian contribution to the IGY. During the planning stages of the IGY, he proposed a program of “world-wide study of cosmic ray variations with standardized equipment.”⁴⁶ The Prime Minister of India, Jawaharlal Nehru, was personally interested in the total work of the IGY, including the optical tracking.⁴⁷ Harvard Astronomer Fred Whipple commented that “it seems to me entirely fitting that India have a leading role in this truly international undertaking.”⁴⁸

⁴⁵ “India will track Satellite Orbits: New Delhi Plans to help in International Geophysical Year,” *New York Times*, May 19, 1957.

⁴⁶ K.R. Ramanathan, “Peaceful Uses of Space,” in Padmanabh Joshi, Vikram Sarabhai. P. 113.

⁴⁷ Memo Fred Whipple to K.S. Krishnan, February 11, 1957, “Satellite Tracking Program,” Satellite Tracking Station Records, 1956-1968, box 61, Smithsonian Institution Archives, Washington DC.

⁴⁸ Ibid.

Table 1: Geographical Distribution of Indian Stations that participated in IGY⁴⁹

Meteorology	Gulmarg, Amristar, Delhi, Jodhpur, Mt. Abu Calcutta –Haringhata, Napur, Veraval, Bombay, Poona Waltair, Madras, Kodaikanal, Trivandrum, Port Blair
Geomagnetism	Dehra Dun, Alibag, Kodaikanal
Aurora and Airglow	Gulmarg, Mt. Abu, Calcutta – Haringhata, Dharwar, Poona.
Ionosphere	Delhi, Benaras, Ahmedabad, Haringhata (Calcutta), Bombay, Poona, Waltair, Madras, Tiruchirapalli, Kodaikanal, Trivandrum.
Solar Activity	Hyderabad, Kodaikanal
Cosmic Rays	Gulmarg, Darjeeling, Ahmedabad, Calcutta, Kodaikanal, Trivandrum
Latitude and Longitudes	Dehra Dun, Naini Tal, Delhi

Optical Tracking of Artificial Satellites⁵⁰

As stated earlier, one of the important programs that was planned during the IGY was the launching of satellites by the then super powers. A satellite that is placed in orbit needs to be tracked for understanding various geophysical phenomena -- upper atmosphere, celestial mechanics, earth's gravity field, geometrical geodesy etc. There are

⁴⁹ Indian National Committee, The international Geophysical Year 1957-58, CSAGI National Reports: India, NAS Archives, Washington D.C.

⁵⁰ For a detailed study on the establishment of tracking stations in India see, Teasel Muir Harmony, "Tracking Diplomacy: The International Geophysical Year and American Scientific and Technical Exchange with East Asia," in Roger D. Launius, James R. Fleming, and David H. DeVorkin, eds., *Globalizing Polar Science: Reconsidering the International Polar and Geophysical Years*, (New York, NY: Palgrave Macmillan, 2010). I would like to thank Teasel for sharing her work on the tracking station in Naini-Tal. I visited the SI archives and read all the papers related to the establishment of Baker-Nunn camera in India. I hope my gleanings from the papers would be complementary to her work and will throw more light on US-India relations in space.

four ways of tracking an Earth satellite – radio, radar, optical and precision laser.⁵¹ There were two ways to track a satellite optically. First, through visual tracking by trained personnel, mostly amateurs, looking at satellites directly through their naked eye using small table top telescopes. This method of observing a satellite was called project *Moonwatch*.⁵² A second, more precise method involved a system composed of a telescopic wide angle camera and precision timing equipment specially housed in observatories. The pictures taken using this special equipment are further interpreted by experts to get data.

Since a satellite in orbit is just like any other object in the universe the task of observing and studying them fell to the domain of astronomers. This new and challenging endeavor attracted the enterprising Harvard astronomer Fred L. Whipple, the new Director of the Smithsonian Astrophysical Observatory (SAO) located on the campus of Harvard College Observatory (HCO), Cambridge, Massachusetts.

Originally the SAO was located in Washington D.C. under the directorship of L. B. Aldrich. After his retirement, the then secretary of the Smithsonian, Leonard Carmichael, appointed Whipple with an agenda of enlarging the research activities. The observatory was moved from Washington D.C. to HCO in 1955. Since its beginning HCO was the Mecca for budding astronomers. Manali Kallat Vainu Bappu from India would come here and get his PhD entitled *The Problem of Wolf-Rayet Atmospheres* in August 1, 1951, under the guidance of Astronomer Donald Howard Menzel, who was

⁵¹ D.G. King-Hele, “Review of Tracking Methods,” *Philosophical Transactions for the Royal Society of London, Series A, Mathematical and Physical Sciences* 262, 1124 (1967): 5-13.

⁵² This is called as moonwatch telescopes. They generally served as an interim method before photographic tracking. A moonwatch team was established in Delhi in 1957. For more on the story of Moonwatch see Patrick McCray, *Keep Watching the Skies!: The Story of Operation Moonwatch & the Dawn of the Space Age* (Princeton: Princeton University Press, 2008).

also the Director of the observatory.⁵³ At that time Whipple was the Chairman of the Department of Astronomy and also Bappu's teacher. Jawaharlal Nehru during this official visit to the United States in the early nineteen fifties, made a visit to HCO.

Fred. L. Whipple was an academic, with extensive connections with the military and navy and had been involved in tracking rockets optically using photographic techniques, under the name the Harvard Meteor Program.⁵⁴ Due to his prior acquaintance he proposed to track the satellites that would be launched during IGY. In late 1955, the SAO was granted the responsibility of establishing a network of tracking stations across the globe by the U.S. National Academy of Sciences (NAS) and the National Science Foundation (NSF) and the US National Committee for the IGY. The whole project was designated the Smithsonian Satellite Observing Program. It neatly dovetailed with Whipple's interests in establishing networks all around the world and he believed that this new endeavor "would foster new techniques that would improve the SAO research program."⁵⁵

Whipple orchestrated the satellite tracking program with J. Allen Hynek, Associate Director in charge of the satellite tracking program. Karl G. Henize was made Senior Astronomer in charge of Photographic Tracking Stations. SAO took the responsibility of providing the camera and associated equipment on a loan basis. For the

⁵³ M.K.V. Bappu, *The Problem of Wolf-Rayet Atmospheres*, Thesis, (PhD) Harvard University, 1951.

⁵⁴ Whipple was born on November 5, 1906 in Red Oak, Iowa. He took a position in Harvard College Observatory in Cambridge, Massachusetts soon after completing his PhD from Berkeley in 1931. Apart from orchestrating worldwide network of optical satellite tracking facilities as the SAO Director (1955-1973), he was well known around the world for his research on comets-- he correctly theorized them early on as "icy conglomerates." He also invented the "Whipple Shield" which protected satellites orbiting the earth from meteor encounter. At the age of 92 he did work on a NASA space probe – Contour mission. He died on August 30, 2004 at the age of 97. Today the SAO astronomical facility which he established at Mt. Hopkins in Southern Arizona is named after him. <http://www.cfa.harvard.edu/about/flwhipple.html>; "Fred Whipple, astronomer, died on August 30th, aged 97," *The Economist*, September 13th, 2004.

⁵⁵ Annual Report of the Smithsonian Institution, 1957 (Washington D.C.: Smithsonian Institution Press, 1957), 69, cited in Teasel, p. 281.

computation of data, the International Business Machines Corporation (IBM) and Computations Laboratory at Massachusetts Institute of Technology (MIT) came in handy. Whipple noted that, without their help, it was “virtually impossible” to undertake this mission. He and his team of astronomers had the “imagination and managerial skill” required to track the satellites in orbit. Support/patronage for such a mammoth endeavor of observing satellites in different geographic regions came from NAS and the US National Committee for the IGY.⁵⁶

The next task for Whipple and his team was to contact astronomers in twelve countries for establishing observatories. Placing the observatories in other countries required extensive diplomatic negotiations. The team had to go through the US State Department to “ensure a maximum of cooperation from the local governments.”⁵⁷ Whipple contacted Indian scientists in the beginning of 1956 to see if they had any interest in the endeavor. The Indian National Committee for the IGY quickly grasped the opportunity and assigned UPSO the task of collaborating with the SAO for undertaking three tasks: Photography of the moon with a Markowitz Camera, Optical Tracking of Artificial earth satellites and visual observations of aurorae.⁵⁸ The Indian Committee for the IGY appointed M.K. Vainu Bappu, the then director of UPSO to be in charge of the Satellite-Tracking program in India in April 1957, and he was given the responsibility of

⁵⁶ J. Allen Hynek and Fred L. Whipple, “Preliminary Results From Optical Tracking of US Earth Satellites,” in G.F. Schilling, ed., *Status Reports on Optical Observations of Satellites 1958 Alpha and 1958 Beta* (Cambridge, Mass: Smithsonian Institution Astrophysical Observatory, 1958); <http://www.cfa.harvard.edu/about/flwhipple.html> (accessed on March 23rd 2011)

⁵⁷ Nelson Hayes, *Trackers of the Skies* (Washington: Smithsonian Institution, 1967), p. 14.

⁵⁸ The U.S. Naval Observatory provided UPSO, a 25-cm telescope fitted with a camera (Markowitz dual motion camera) to take photographs of the moon to calculate lunar center and through that the position of the observer. 284 photographic plates were sent to the United States for analysis. The aurora project never got started because from Naini Tal none could be observed. See S.D. Sinval, “The Uttar Pradesh State Observatory – Some Recollections and some history,” *Bulletin of Astronomical Society of India* 34 (2006): 65-81

establishing the unit with the equipment provided by the SAO. Before I talk about UPSO-SAO collaboration, I will give a brief history of UPSO.

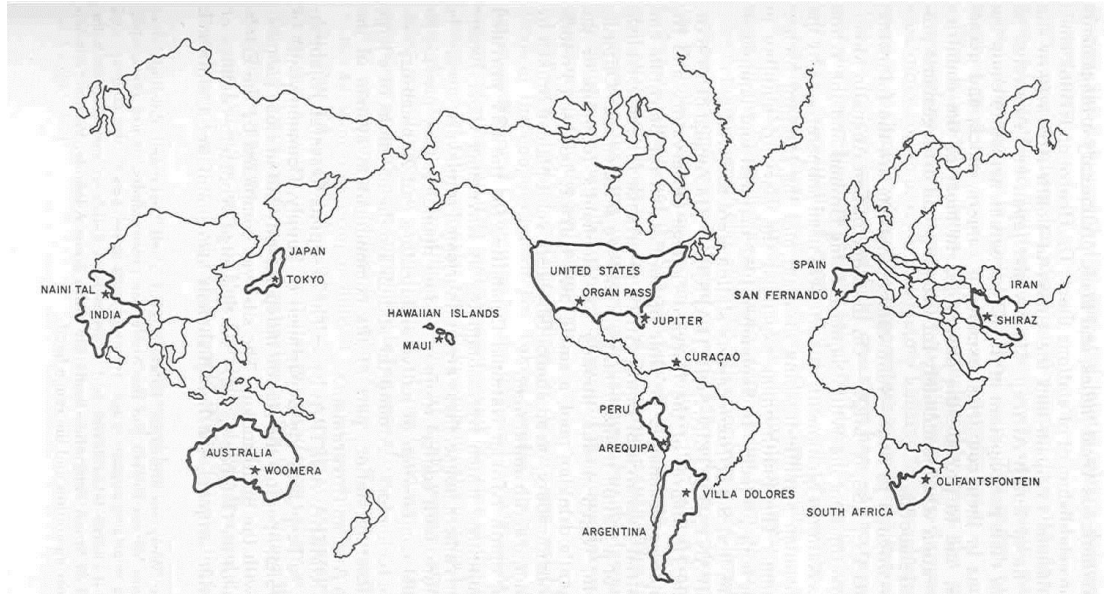


Figure 1. Sites of Baker Nunn Camera Stations. Source – Samuel Hayes, *Trackers of the Skies*

UPSO

A Hindu Brahmin, Babu Sampurnanadji – a teacher turned political leader, along with his mathematician friend, Avadhesh Narain Singh, out of sheer fascination for astronomy started planting seeds for establishing an observatory in Benaras (now Varanasi). A committee was formed in 1952 to foresee the planning and purchase of equipment. Decommissioned instruments -- a telescope and time unit, were purchased from Europe and established at Sarnath and the Government Sanskrit College, Benaras. By April 1954 the observatory was up and running with A.N Singh as the honorary director. After the sudden demise of Singh in July of 1954, Vainu Bappu was appointed

as the Chief Astronomer.⁵⁹ The observatory was called the Uttar Pradesh State Observatory (UPSO), under the ministry of Cultural Affairs and Scientific Research, Uttar Pradesh. It was customary for foreign trained scientists to revamp the existing facilities and make them “modern,” Bappu, began making changes. He wanted to relocate the observatory from the plains of Uttar Pradesh to the hills of Naini Tal at Manora Peak and equip it with more advanced scientific instruments, a full fledged library, and supporting equipment. In simple terms, he wanted to establish a “Harvardian” Astrophysical Observatory at Manora Peak (longitude 79 degrees 27’ E, 29 degrees, 22’ N, altitude 1951 m). The move to Naini Tal began in November 1955 and steps were taken to acquire the land at Manora Peak -- 48 hectares, to establish a world class observatory. It was during this time that the SAO approached India for establishing an optical tracking facility and established one before the establishment of the main observatory at Manora Peak. The project was finally completed on 20 November 1961. UPSO became a State Observatory, Naini Tal (SON) in November 2000 after the UP State was divided into two states. On March 2004, the State Observatory became an autonomous institute under the Department of Science and Technology, Government of India. The facility was rechristened the Aryabhata Research Institute of Observational Sciences (ARIES).⁶⁰

Establishing the Tracking Station

⁵⁹ He is well known around the world for Bappu-Bok-Newkirk Comet and Wilson Bappu Effect. On 31st March 1960, Bappu moved to Kodaikanal to head the observatory there.

⁶⁰R. Ramachandran, “An Institute Reborn,” *Frontline* 21, no. 9 (May, 2004), <http://www.frontlineonnet.com/fl2109/stories/20040507002209000.htm> (accessed on March 24, 2011); Ram Sagar, Aryabhata Research Institute of Observational Sciences: reincarnation of a 50 year old State Observatory of Nainital, *Bulletin of Astronomical Society of India*, Vol. 34, no. 2 (2006): 37-34; S.D. Sinval, “Uttar Pradesh State Observatory,” *Bulleting of Astronomical Society of India* 1, no. 2 (September 1973): 23-24.

For establishing the facility in Manora Peak, Naini Tal, there was traffic of experts between the SAO and UPSO. During the early planning stages many requests were made by the SAO inquiring about weather, twilight conditions versus daylight or night conditions, difficulty of physical access, living conditions for an American observer, and other such information”⁶¹ Allan Hynek visited Naini Tal on June 2, 1957 for selecting a station site in coordination with Vainu Bappu. Elwyn C. Balch, Engineering Consultant, in charge of tracking station construction, went to India in December 1957 for station construction and for receiving, transporting and erecting the camera equipment. He also addressed problems with respect to power (in India the voltage is 240 whereas the equipment was designed to operate only on 110 v, 50 or 60 cycle A.C., so the power had to be stepped down in order for the equipment to function), and water supply, and communications between UPSO and the SAO, Cambridge, Massachusetts.⁶²

The SAO made plans to ship the satellite tracking camera, modified Norman Crystal clock and other ancillary equipment, such as the frequency control unit, the automatic transfer switch for emergency power, the 2.5 kw emergency power generator, a standard developing tank for developing images taken by the camera, and a special projector for viewing the film. For training the Indian astronomers in the use of the Baker-Nunn camera, a resident astronomer was sent to India. Bappu was also invited to

⁶¹ Memo, Fred. L. Whipple, January 3, 1957, Smithsonian Astrophysical Observatory, Satellite Tracking Program, Satellite Tracking Station Records, box 18, Smithsonian Institution Archives, Washington D.C.

⁶² Memorandum, Kenneth H. Drumond to Vainu Bappu, 27 November 1957, Smithsonian Astrophysical Observatory, Satellite Tracking Program, Satellite Tracking Station Records, box 18, Smithsonian Institution Archives, Washington D.C

the US for training and instruction for 6 weeks. A conference in Moscow stopped him from going.⁶³

Resident Observer in India

For assisting the general SAO work, Whipple, Hynek, Henize and other members of the Smithsonian staff jointly selected observers. The selection committee mainly looked for people who had “eagerness, enthusiasm, a spirit of adventure and especially a sense of responsibility.” They would not only operate the Baker Nunn camera but also “drive nails,” and “work cooperatively and efficiently with scientists but also deal with strangers in strange lands.”⁶⁴ Samuel Whidden, who had earlier experience in the Harvard Meteor Program, impressed the interview committee and he was the first observer to be selected. He was well trained in the operation of a Baker Nunn before he was sent to India to assist in its operation. Just before leaving for India, he married Martha Holt, who was also of the satellite tracking project and they both ventured into an alien land. Marty would be his close companion and she typed all the correspondences to the SAO board regarding the status of the observatory. Whidden was also informed about Indian “neutrality” and given copies of speeches by John Foster Dulles -- the Goal of our Foreign Policy; Our Foreign Policies in Asia and others.⁶⁵ Upon arrival in January 1958, the couple would take residence at Edwinstone Cottage, in Naini Tal, India.

His early enthusiasm for India quickly faded into despair. Though Whidden and Vainu Bappu were classmates at Harvard (1949-1951), they did not get along well. From

⁶³ Fred L. Whipple to M.K. Vainu Bappu, November 8, 1957, Smithsonian Astrophysical Observatory, Satellite Tracking Program, Satellite Tracking Station Records, box 18, Smithsonian Institution Archives, Washington D.C.

⁶⁴ Nelson Hayes, *Trackers of the Skies*, pp. 36 -37.

⁶⁵ Memorandum, J. Allen Hynek, to Samuel Whidden, 11 March 1958, Smithsonian Astrophysical Observatory, Satellite Tracking Program, Satellite Tracking Station Records 1956-58, box 18, Smithsonian Institution Archives.

the beginning friction started to develop. It all began with who would control the SAO station in Naini-Tal. Coupled with that, he disliked the general living conditions, the slow pace of construction work at Manora Peak for establishing the facility, loss of equipment during shipping, the Indian attitude toward science and technology, the delay in starting observation at the facility (by March of 1958, 9 out of 12 were operational.).⁶⁶ He would leave India on December 15, 1958, frustrated.

Problems of Jurisdiction

Even before establishing the station in Naini Tal, the question of who would be in charge of the observatory was raised by Vainu Bappu. Although the issue of jurisdiction was not given much importance by the Americans initially, they soon realized that it became a sensitive and “touchy subject” for the Indian scientific establishment. The jurisdiction problem arose while discussing the prospect of a written agreement between the Indian Committee for the IGY and the SAO in the Fall of 1957. Extensive correspondence between Fred Whipple, Vainu Bappu, Samuel Whidden, Alan Hynek, E.C. Balch, is a clear testimony of how postcolonial India exerted her sovereignty.⁶⁷

The first appearance of a problem appears in Whidden’s correspondence to Allen Hynek on February 11, 1957. He said that, “unless we act immediately, we are in danger of losing *our* (emphasis mine) station.” Based on archival papers that I have consulted it appears that the SAO wanted to have control over the station at UPSO. However, when Whidden arrived in India, Bappu made it clear that UPSO would be an independent one like the one established in Japan and Australia. The station with its equipment and

⁶⁶ For more on their experiences in India see, Eloise Engle and Kenneth H. Drummond *Sky rangers: Satellite tracking around the world* (New York: John Day, 1965).

⁶⁷ Memorandum, E.C. Balch to Henize, Jan 7, 1958, Smithsonian Astrophysical Observatory, Satellite Tracking Program, Satellite Tracking Station Records 1956-58, box 18, Smithsonian Institution Archives.

operation were to be directly under the jurisdiction of the Uttar Pradesh State Government. Bappu reasoned that the UP Government and the Indian Council of Scientific and Industrial Research (CSIR) donated funds for operating the station and it would be difficult to justify to the Indian Parliament that the financial support from India would be going to a US observatory on Indian soil. The sum donated would not be accepted by parliament as a “gift” to the American Government. In addition to this, Bappu also pointed out that the tracking program did not complement the current work at the UPSO. Even the *prestige* value of having one of the 12 world satellite tracking stations apparently was lost if it was a Smithsonian rather than a UP station. He would accept an American observer at this station only as a technical advisor without authority over operation or jurisdiction over equipment. He also stated that the UP observatory was not interested in retaining permanently any of the equipment sent by the Smithsonian and after usage it would be sent back to SAO.⁶⁸

In addition to the jurisdiction problem, Bappu also showed serious concern over the presence of American Army Map Service Personnel, Sgts. Jack D. Erskine (who arrived in India on 7 Feb 1958) and Aubrey Simons (March 1958). They were sent by the SAO to operate Cine-Theodolites, as an interim measure before the arrival of the Baker Nunn camera, to observe satellites. The main concern for Bappu was that Naini Tal was in a restricted border area, all maps for that region were classified by the National Government, the mere presence of army personnel, Bappu believed, would jeopardize the operation of the station.⁶⁹

⁶⁸ Letter, Samuel B. Whidden to J. Allen Hynek, 11 February 1958, Smithsonian Astrophysical Observatory, Satellite Tracking Program, Satellite Tracking Station Records 1956-58, box 18, Smithsonian Institution Archives.

⁶⁹ Ibid.

The officials at the SAO discussed the jurisdiction problem and agreed to Bappu's demands. "We are willing for the Indian Station to be operated in the same manner as that of Australia and Japan. This, of course, means that India bear the brunt of the administrative costs and some agreement be reached regarding ownership of equipment....We will certainly bend over backwards if necessary to insure smooth operation and international cooperation with India and the Uttar Pradesh State Observatory."⁷⁰ Regarding the question of the presence of military personnel, Bappu came to a compromise, he said they will be "removed only if the Government reaction against them is strong."⁷¹

However, because of the prevailing political situation and the general caution expressed by Bappu, Whidden stated that he and his team would direct their energy toward the Baker-Nunn camera, and he wanted to return the theodolite to where it belonged -- Patrick Air Force Base.⁷² Though the theodolites were never put to use, Whidden retained Erskine and Simons for installing the Baker Nunn camera, he said that "their presence will prove their valuable safeguard during the installation and erection of the Camera."⁷³

⁷⁰ Kenneth H. Drummond to Samuel B. Whidden, 20 February 1958, Smithsonian Astrophysical Observatory, Satellite Tracking Program, Satellite Tracking Station Records, box 18, Smithsonian Institution Archives, Washington D.C.

⁷¹ Samuel Whidden to Kenneth H. Drummond, "Station Jurisdiction," March 1, 1958, Smithsonian Astrophysical Observatory, Satellite Tracking Program, Satellite Tracking Station Records, box 18, Smithsonian Institution Archives, Washington D.C.

⁷² Samuel Whidden to Karl G. Henize, 26 April 1958, Smithsonian Astrophysical Observatory, Satellite Tracking Program, Satellite Tracking Station Records, box 18, Smithsonian Institution Archives, Washington D.C.

⁷³ Samuel Whidden to Karl G. Henize, 25 April 1958, "Earth Satellite Optical Tracking Station UPSO," Smithsonian Astrophysical Observatory, Satellite Tracking Program, Satellite Tracking Station Records, box 18, Smithsonian Institution Archives, Washington D.C.

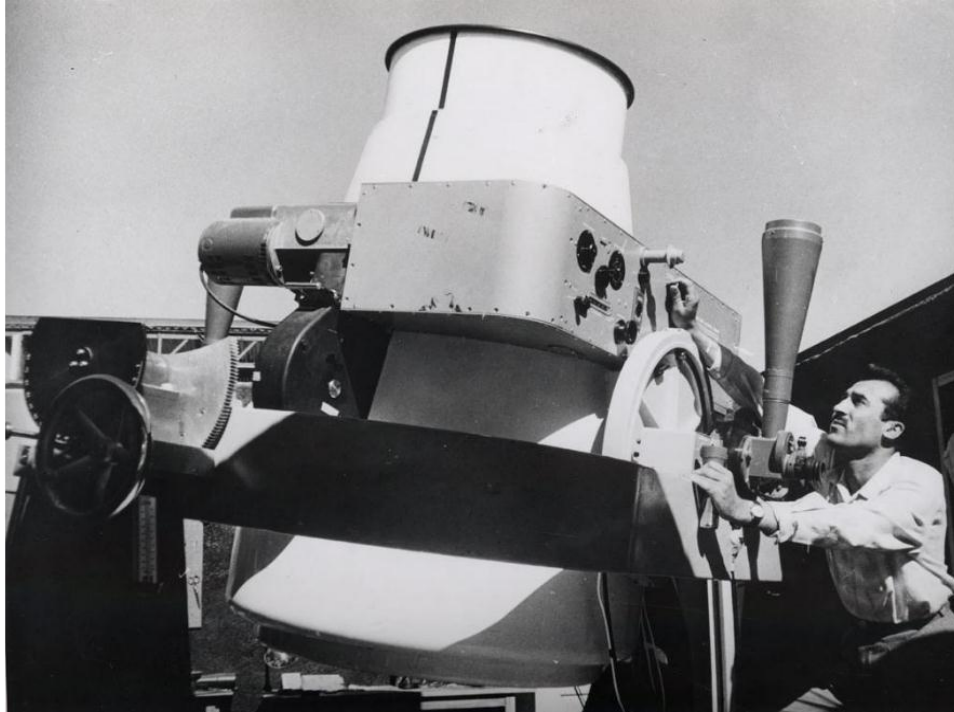


Figure 2: Baker Nunn Camera

Source - Smithsonian Institution Archives

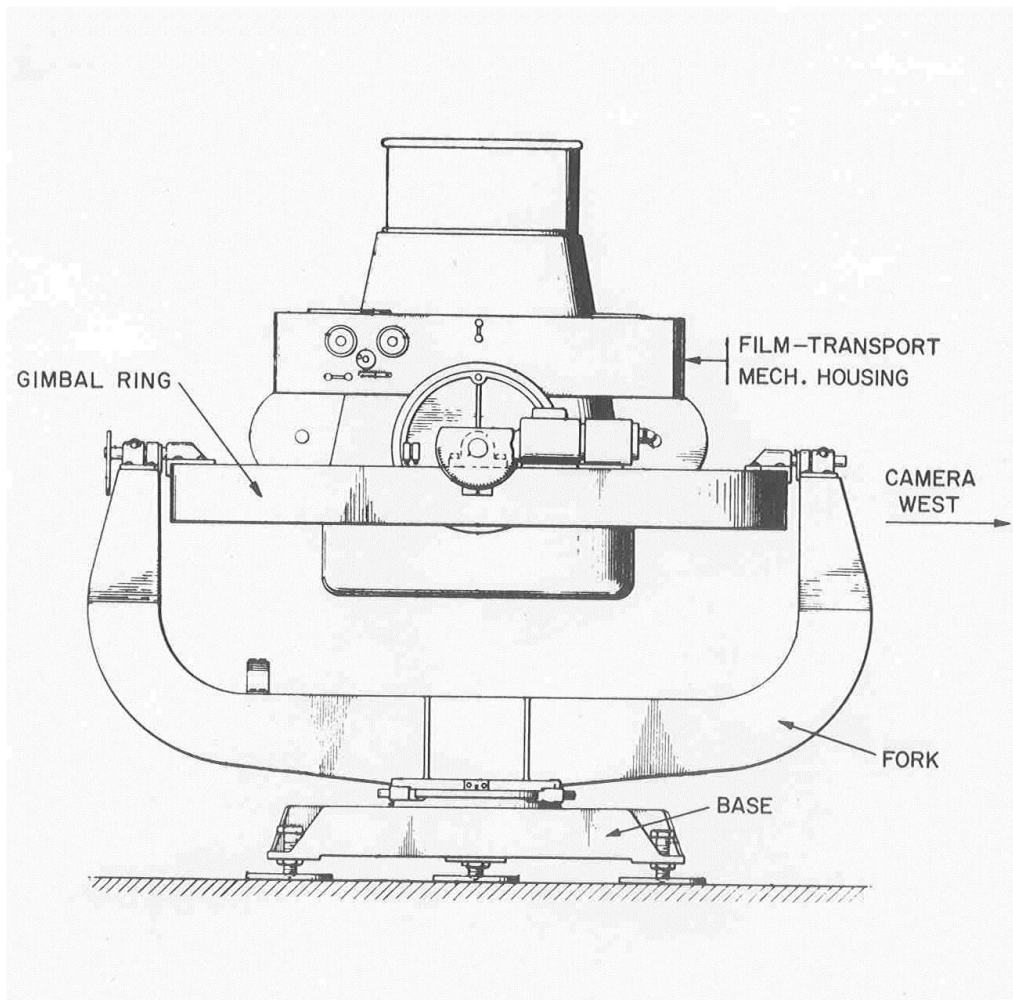


Figure 3. Baker Nunn Camera North side

Source: Baker Nunn Camera Manual.⁷⁴

⁷⁴ Edwin A. Jeffrey and Edward H. Jentsch, *Baker-Nunn Camera Manual, Vol. 1 and 2* (Cambridge MA: Smithsonian Astrophysical Observatory, 1967). I would like to thank David Devorkin for providing me this manual.

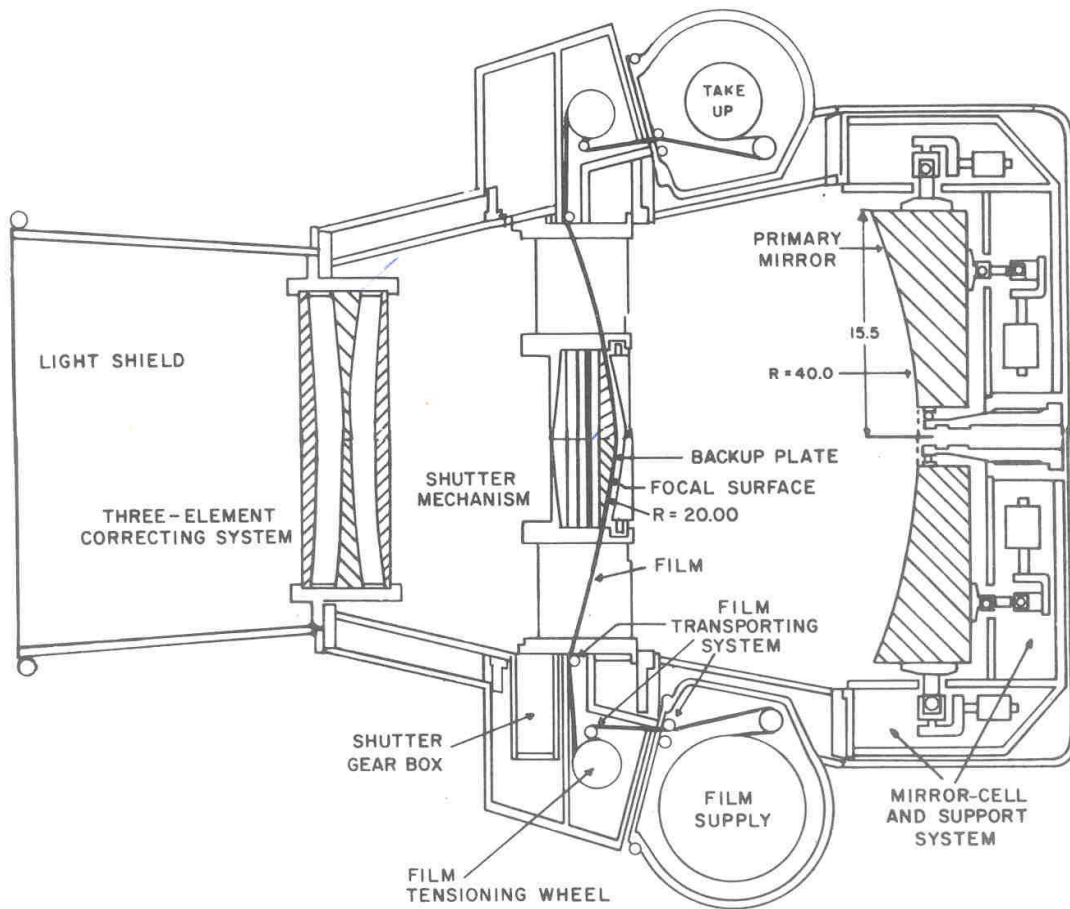


Figure 4: Baker-Nunn Camera, Section North to South.

Source: Baker Nunn Camera Manual.

The Baker-Nunn system has a telescopic 3-axis, 20 inch aperture, f/1 camera mounted on a mechanical platform. They can track satellites measuring 20 inches and above in diameter, at a distance of 2000 miles. They measured 12 feet long, and weighed roughly three tons. The optical unit of the camera was specially designed by James G. Baker and the mechanical system for operating the camera was designed by Joseph Nunn. Hence the name *Baker Nunn*. The optical and mechanical unit was manufactured by two firms -- Perkin-Elmer Corporation, Boller and Chivens, inc, both located in Pasadena, California. The system also included a Norman electronic time standard, which indicates the time of observation to 1/10,000 of a second to be photographed simultaneously with the satellite. The camera was capable of taking 60 photographs a minute. Each camera was valued around \$ 100,000. The Military Air Transport Service (MATS), shipped the camera to New Delhi and it was taken to Naini Tal by rail and road. The camera reached Naini Tal on April 1958. Samuel Whidden, Erskine and Simons with the help of Indian assistants installed it at the SAO facility in Manora Peak in August, and satellites were tracked regularly from September 1958 onwards. The photographs were taken, washed and developed and sent to SAO headquarters for further study. The data was transferred from Naini Tal to Cambridge through Radio Corporation of America (RCA) Communications, Inc. This was made possible through the Deputy Director General of India's Overseas Communications Service at Bombay. By the end of 1958, the Naini Tal facility was making regular observations. Between April – May 1959 ,the worldwide network made 2, 902 observations, 300 of which came from the station in India.⁷⁵

⁷⁵ Anthony E. D'Souza, "Naini Tal Satellite Tracking Station now in operation," US Information Service, attached in memo sent by Samuel Whidden to Karl G. Henize, 23 November 1958, Smithsonian

While UPSO was involved in satellite tracking, other scientific institutions were also collaborating with the United States in the realm of space sciences and applications. At the National Physical Laboratory, New Delhi, “a model of earth’s atmosphere was developed using the U.S. satellite.” The India Metrological Department analyzed the data acquired through the Tiros meteorological satellite when it passed over India and arrangements were made for other geophysical observations like radiosonde, radio wind and cloud cover. At PRL, Ahmadabad cosmic ray studies were undertaken.⁷⁶

Fred Whipple, seeing the promises of growth of space sciences expressed to Arnold Frutkin, who would later become the Associate Director for international relations at NASA, that “I feel that the National Astronautics Agency can indeed cover many of the functions of the IGY, and....it seems to me that some of the research we are doing in the IGY should be continued in the space studies by our National Astronautics Agency.”⁷⁷ Accordingly, NASA’s initial overtures in space sciences were an extension of the work conducted during the IGY.

Following the launch of Sputnik by the Soviet Union in 1957 the United States, through the newly formed NASA, made several overtures to lure emerging ‘third world’ countries to participate in the space program by experimenting with sounding rockets. Some countries, seeing the prestige associated with modern space technologies, immediately responded to the offers made by NASA to establish sounding rocket stations and develop nascent space programs at home. Working on space sciences offered the

Astrophysical Observatory, Satellite Tracking Program, Satellite Tracking Station Records, box 18, Smithsonian Institution Archives, Washington D.C.

⁷⁶ COSPAR Information Bulletin No. 6, September 1961, Reports on National Activities presented at the fourth COSPAR Meeting Florence, Italy, April 1961.

⁷⁷ Hearings before the select subcommittee on Astronautics and Space Exploration, 85th Congress, Second Session, on H.R. 11881, 1958, quoted in Arnold Frutkin, *International Cooperation in Space*, p. 28

newly decolonized states and developing countries the promise of a march toward modernity – the native elite viewed experimenting with rockets as a source of pride, prestige and a visibility among nation-states. However, very few countries that accepted the offers (tracking stations and sounding rocket facilities) actually sustained and built their own space programs for socioeconomic and strategic needs.

Arnold W. Frutkin

A graduate of Harvard College and Columbia University, Arnold W. Frutkin, joined NASA in 1959 and headed the Office of International Affairs for the next 18 years. Before joining NASA he was the Deputy Executive Director of the U.S. National Committee for the International Geophysical Year (IGY) and he also served in the U.S. Navy in the Pacific during WWII. While at NASA he won numerous awards, notable ones being NASA Exceptional Service Medal in 1968 and NASA Distinguished Service Medal in 1973. He is the author of an important book on NASA's external relations entitled *International Cooperation in Space* and also numerous articles and conference presentations.⁷⁸ He retired from Federal service on June 22, 1979 after serving very briefly as Deputy Associate and Associate Administrator for External Relations at NASA.

Keeping the triune goals of maintaining American leadership in space, serving U.S. foreign policy objectives and finally advancing the frontiers of scientific knowledge and reaping the intellectual and technological benefits, Arnold Frutkin, through a distinct set of guidelines, coordinated many international cooperative space activities.

Frutkin's guidelines showed marked differences from other cooperative ventures, especially the "not so successful" attempt to foster international understanding through

⁷⁸ Arnold Frutkin, *International Cooperation in Space* (Englewood Cliffs, N.J.: Prentice-Hall, 1965).

Atoms for Peace derived from the Atomic Energy Act of 1954. “Great expectations had been raised but realization was slow and disappointing” he said. In most of the cases “cooperation simply meant bestowing U.S. – made reactors at U.S. expense, with U.S. technicians, in the hope that U.S. –trained nationals could someday take them over.”⁷⁹ Seeing how international cooperation evolved in the nuclear field, Frutkin opted for “new realism” to orchestrate international cooperation in space activity. The new realism manifested itself in the form of a set of guidelines which I list here verbatim: “literal cooperation without the passing of dollars; solid rather than token program content; a project-by-project procedure; negotiation with central and authorized civilian agencies, on a direct technical, rather than indirect diplomatic basis; encouragement of foreign scientific interests rather than imposition of domestic concepts and stress upon the less sensitive, purely experimental areas, at least to begin with.”⁸⁰

Significant projects undertaken within these guidelines were the global networks of tracking stations for acquiring data from meteorological and earth resource satellites, launch by the US of other countries satellites, integration of foreign experiments on US spacecraft, numerous sounding rocket projects in different countries, training of personnel at select NASA facilities and also at the American Universities, analysis of lunar samples by fifty countries, the spectacular broadcast experiments using the Advanced Technology Satellites (ATS), the Apollo Soyuz mission and Space Lab.

Vikram Sarabhai and NASA

⁷⁹ Walter McDougall, *The Heavens and Earth: A Political History of the Space Age* (New York: Basic books, 1985), p. 207.

⁸⁰ Arnold Frutkin, *International cooperation in Space*, p.35; Also see, John Krige, Angelina Long, Ashok Maharaj, *Contest and Collaboration*, (Forthcoming), (Chapter 1)

The first recorded mention of Vikram Sarabhai expressing an interest in NASA's international cooperative programs was in the Spring of 1961, while he was enrolled as a visiting professor at MIT. Following his previous discussions with world renowned physicists like Bruno Rossi at MIT, James Van Allen at Iowa, and, J. A. Simpson, and P. Mayer at Chicago, Sarabhai told NASA of India's plans to start a space science research program at select facilities: the Physical Research Laboratory (PRL), Ahmadabad; the Tata Institute of Fundamental Research (TIFR), Bombay and the Tata Institute of Nuclear Physics (TINP), Bombay. He also described his plans to recruit trained Indian physicists in European countries and the U.S.

During the meeting with NASA officials Sarabhai explored possible cooperative endeavors that could be mutually beneficial to both NASA and India such as: magnetic fields, solar radio astronomy, geo-magnetism, atmospheric studies from 30-150 kilometers, trapped particles in radiation belts and electro jet studies. In furthering these fields of research he discussed the possibility of a cooperative sounding rocket program between India and NASA and also a telemetry receiving facility at the PRL, Ahmadabad. It was also in this meeting that Sarabhai learned about the work of atmospheric scientist Lawrence Cahill of the University of New Hampshire. Cahill would later visit India to conduct a number of sounding rocket experiments.⁸¹ Seeing the progress India was making towards this emerging field of space sciences, Arnold Frutkin explained to Sarabhai the policy guidelines for international cooperation just mentioned. The international cooperative program was to maintain a two-way channel for the flow of

⁸¹ Memorandum, Wilmot L. Averill- chief, cooperative programs, office of International programs, the participants were Vikram Sarabhai, Upendra Desai, Arnold Frutkin and Averill, June 1, 1961, Special Assistant to the Secretary for Energy and Outer Space, Records Relating to Atomic Energy Matters 1955-1963, box 252, NARA II.

ideas between gifted men and women in United States and abroad, in the framework of their own, or joint, space projects.⁸²

In July 1961, Frutkin sent a memorandum to Vikram Sarabhai for a working arrangement with his PRL situated in Ahmadabad, for the purpose of recording data from the Explorer Number XI Gamma Ray astronomy satellite. The memo gave details about NASA loaning critical equipment that was necessary for observing the satellite. Upon hearing about Sarabhai's willingness to enter into a cooperative relationship, the International Relations Office at NASA, after consultation with the U.S. Department of State, entered a working arrangement with PRL for the establishment of such a facility.⁸³ On 6 September, 1961, PRL received a tracking and telemetry receiving facility. It was the first instrument from NASA to enter India.⁸⁴

These tracking stations became the channel through which NASA began to extend its reach to include other nations for a worldwide data acquisition system for satellites launched by the United States. By 1963, twenty eight such stations in sixteen countries were established.⁸⁵ They not only functioned as scientific instruments for disseminating data for the United States but also served as conduits for host countries to begin their own space programs. Milton C. Rewinkel, the U.S. Consul General, remarked that "It is a

⁸² "International cooperation in Space: What's being done? What of the future?" *Vital Issues*, Centre for Information on America, Washington, Connecticut, Vol XII, Number 8, (Not dated)

⁸³ Recordings of the Faraday rotation of 20, 40, and 41 Mhz transmitted by the U.S.A satellites BE-B and BE-C were regularly recorded from 1964 onwards and the data analyzed to determine the total electron content of the atmosphere up to the satellite height of about 1000km. These have been compared with the maximum electron density at the peak level of the F2 region, *25 years of PRL* (undated, international publication of Physical Research Laboratory), Vikram Sarabhai Archives, Ahmedabad.

⁸⁴ According to the agreement NASA agreed to provide motor driven dual Yagi antenna, 108 Mc pre-amplifier, 108 Mc micro lock receiver, FR-100 tape recorder, two FM discriminators, look angles and time for satellite passes, magnetic tapes and also technical consultants to assist in the installation of the equipments. Memorandum Hugh Dryden, Deputy Administrator NASA, to Homi Bhabha, August 11 1961, RG 59, Central decimal file 1960-63, box 3112, NARA II.

⁸⁵ For detailed study of the global distribution of tracking stations see Sunny Tsiao, 'Read you Loud and Clear.' *The story of NASA's Spaceflight Tracking and Data Network* (Washington D.C.: NASA SP- 2007-4232).

matter of some pride to us, too, that by making America's space knowledge experience and facilities available to foreign scientists, the United States has enabled several other countries to initiate their own space program and develop their own space technology.”⁸⁶

It is also important to mention here that Arnold Frutkin, seeing the instruments going to a research facility -- PRL, informed Vikram Sarabhai his desire for an “exclusive space agency or committee” in India for cooperation purposes:

Based upon our previous discussions, it is my understanding that India may establish a space research committee under Government sponsorship. It would be most desirable if the general program arrangements between us could be related appropriately to such a committee. In the interim, however, we understand from our State Department that your Ministry of External Affairs has approved our proposed cooperative effort in principle. The content of this letter has been provided to your Government at its request so that the necessary arrangements may be made within the appropriate Ministries of your Government. NASA will be pleased indeed to enter into this working arrangement with the Physical Research Laboratory on the Explorer Number XI experiment and hopes that this initial effort will grow into the *centrally coordinated program* (emphasis mine) we have discussed.⁸⁷

Seeing the emerging field of space science and technology, and the promise it offered, Homi Bhabha, the Secretary of Department of Atomic Energy (DAE), carved a niche within DAE in August 1961, for a rudimentary space science and research cell. Before the formation of this cell the Indian National Committee for the IGY has been asked to

⁸⁶ Address, Milton C. Rewinkel - Consul General for the United States of America, January 31, 1963, RG 59, General Records of the Department of State, Central Foreign Policy file 1963, folder SP 15 - Space Vehicle Tracking, box 4184, NARA II.

⁸⁷ Arnold Frutkin's letter to Vikram Sarabhai, July 24, 1961, attached along with the letter was the memo from Walter W. Stuart, Counselor of political Affairs, American Embassy, New Delhi to S. Gupta, Joint Secretary western Division, Ministry of External Affairs New Delhi, RG 59, Central Decimal File 1960-63, box 3112, NARA II.

serve provisionally as the National Space Committee for India adhering to COSPAR. The initial cooperative relations between NASA and India were primarily negotiated by the DAE through Bhabha and Sarabhai.

Homi Bhabha often dovetailed nuclear matters with space science and technology topics during his periodic visits to the United States. On one such visit to NASA Headquarters between November 9 and 15, 1961, he met with Frutkin and talked about possible cooperative programs between India and NASA. He also hinted at the establishment of a “special committee” made up of Indian scientists already active in space related areas. He stated that the committee would be responsible for selecting appropriate programs for India, to train young people in the field of space sciences and technology and also would send representatives to participate in meetings organized by COSPAR. He also projected that the “committee” would become the principal point of contact with NASA. Because of India’s limited economic resources, Bhabha explained that it would not be practical for India to attempt to build rockets and that these would be procured from other countries. In this connection, Frutkin pointed out to Bhabha that many of the existing sounding rockets were under the control of the Department of Defense (DOD) and that some of them, though non-military in nature, were classified. Bhabha was asked to bear in mind that the question of availability must often be subject to security arrangements in force between the governments concerned.⁸⁸

⁸⁸ Memorandum, R.G. Bivins, Jr., Office of International Programs to A.W. Frutkin, November 18, 1961, “Visits to NASA by Dr. Homi J. Bhabha of India,” RG 59, Special Assistant to the secretary for Energy and outer space, Records relating to Atomic Energy Matters, 1944-63, box 250, NARA II. During this trip Bhabha visited GSFC on the morning of November 13 where he was shown the communications and control centers, computing facilities, and the telemetry and time measurement instruments etc. He also met with Upendra Desai who was the Indian resident research associate at GSFC. He visited Wallops on November 14 and was shown all the principal facilities.

NASA at this early phase of cooperative endeavors with India was clearly looking for guidance from the State Department before initiating any discussions on collaborative space ventures with the Indians. The reason for consultation with the State Department even for space science research was due to the absence, unlike with Pakistan or Japan, of any security arrangement with India for the protection of sensitive or classified information. Also, the State Department papers indicate that the officials were aware of the presence of Soviet scientists and technicians, including a number of Soviet airmen, and the close cooperation that India sought with the USSR for cooperation covering peaceful uses of atomic energy, operation of nuclear power stations and the production and processing of uranium. The U.S. State Department officials generally viewed Bhabha in a different light -- as one expressing communist sentiments and also to be involved in "communist front activities." The officials saw him as a potential technocrat who could "utilize contacts with both sides involved in the East-West struggle in order to achieve the most advantageous opportunities to advance his objectives." As a result cautionary memos were sent to NASA officials suggesting that Homi Bhabha might use Indian Prime Minister Nehru's official visit in 1962 "to achieve some concrete arrangements for space research cooperation."⁸⁹

Frutkin's resultant reply to Bhabha after his visit contained the possible areas of cooperation. He saw the establishment of a sounding rocket range close to the geomagnetic equator to be "most desirable" for launching scientific payloads prepared by PRL and TIFR for detecting high energy neutrons emitted from the Sun during the periods of great solar activity. Frutkin's motivation for cooperating in a sounding rocket

⁸⁹ T. Eliot Weil to Wreatham E. Gathright, "Proposed Visit of Dr. Homi J. Bhabha," October 5, 1961, RG 59, folder Ccooperative space program, box 250, NARA II.

program with India was the perceived benefit of getting scientific data of the tropical atmosphere and also to create an international sounding rocket base for international cooperation under the auspices of the United Nations. NASA's early space science programs neatly merged with India's long scientific tradition of studying elusive cosmic rays and the sun's ultra violet rays. This work had been started by physicists like Megnad Saha, who was later followed by scientists like K.R. Ramanathan,⁹⁰ Raman Pisharoty, Homi Bhabha, Vikram Sarabhai, and others.⁹¹

Secondly, he suggested the launching of Indian sodium vapor payloads to investigate various properties of the upper atmosphere near the geomagnetic equator and the possible launchings of rockets during the International Quiet Sun Year (IQSY) as a part of a proposed large scale effort to make meteorological and ionospheric soundings on a synoptic basis.

Thirdly, he stressed the importance of participation in low altitude meteorological rocket observations in conjunction with the International Indian Ocean Expedition

⁹⁰ K. R. Ramanathan was an expert on atmospheric ozone and a former president of the International Union of Geodesy and Geophysics had directed the laboratory since its inception in the late 1940s. Both Sarabhai and Ramanathan have led important programs of ground based research programs which expanded under the stimulus of the International Geophysical Year (IGY) and the International Years of the Quiet Sun (IQSY). Using counters and monitors at several sites in India, and at Chacaltaya in Bolivia, Sarabhai and his colleague R. P. Kane, N.W. Nerurkar, G.L. Pai, S.P. Pandya, U.R. Rao and others studied cosmic rays as they are influenced by the sun's magnetic field.

⁹¹ In the 1940s, the Indian Institute of Science (IISC) in Bangalore, the Bose institute in Calcutta, and the Muslim University at Aligarh were effectively conducting cosmic ray research. Teams of scientists—for example, Max Milliken and his colleagues, a group headed by Homi Bhabha at IISC, and another team under A.P. Thatte at TIFR—conducted cosmic ray experiments using rubber balloons. Vikram Sarabhai and K.R. Ramanathan started research into space sciences, which led to the establishment of PRL in 1947. By the mid 1950s PRL had become an international centre for cosmic ray research. Meanwhile, TIFR established a basic infrastructure, including radio interferometers, large radio telescopes, and a facility for making plastic balloons. For more on the development of scientific institutions in India, see Anderson R.S. *Building Scientific Institutions in India: Saha and Bhabha*, Occasional Paper Series, No. 11 (Montreal: McGill University Press, 1975), p.31, Padmanabh K. Joshi, ed., *Vikram Sarabhai*, p. 112; Angathevar Baskaran, "From Science to Commerce," *Technology in Society* 27 (2005): 155-179; Rajesh Kochhar, "Science as a Symbol of New Nationhood: India and the International Geophysical Year 1957-58," *Current Science* 94, no. 6, (25 March 2008): 813-816; S. Reddy, "India's Forays into Space," *International Studies* 45, no. 3 (2008): 215-245; Indira Chowdhury and Ananya Dasgupta, *A Masterful Spirit Homi J. Bhabha, 1909-1966* (New Delhi: Penguin Books, 2010).

(IIOE). After stating the possible avenues of cooperative endeavors, Frutkin drafted a Memorandum of Understanding (MoU), between India and NASA outlining the broad areas of mutual program interest and indicating the general guidelines for the conduct of the program.⁹²

The Indian Committee on Space Research (INCOSPAR)

On February 1962, with recommendations from the Scientific Advisory Committee to the Cabinet, the Government of India, the Indian National Committee for Space Research (INCOSPAR) was formed within the Department of Atomic Energy (DAE) under the chairmanship of Vikram Sarabhai to manage all aspects of space research in the country. The first meeting of INCOSPAR was held on 22 February, 1962.⁹³ The establishment of this institution brought organization and coordination to isolated space activities that were carried out in different regions across India. This new committee coordinated all space research activities, both national and international, until a separate Indian Space Research Organization (ISRO) was formed in 1969. INCOSPAR, however, did not cease to exist; it was reconstituted under the Indian National Academy of Science (INAS) and retained the responsibility for the promotion of international cooperation in space research and exploration and peaceful uses of outer space, and liaison with the United Nations Committee on Space Research (COSPAR).

INCOSPAR consisted of eminent scientists, who advised the Indian government on the promotion of research and exploration of space and its utilization for peaceful purposes both nationally and internationally. The initial group that orchestrated

⁹² Memorandum, Arnold Frutkin to Homi Bhabha, December 12, 1961, folder Cooperative Space Program, RG 59, box 250, NARA II.

⁹³ Memorandum, R. Shroff to Arnold W. Frutkin, RG 59, Special Assistant to the Secretary for Energy and Outer Space, Records Relating to Atomic Energy Matters 1955-1963, box 259, NARA II

INCOSPAR were scientists who participated in the IGY: Vikram Sarabhai was from PRL, Vainu Bappu was the Director of Astrophysical Observatory, M.G.K. Menon was the Dean, physics faculty at TIFR, A.P. Mitra was the Assistant Director, NPL, New Delhi. P.R. Pisharoty was the Director of Colaba Observatory, Indian Meteorological Department, Colaba, Bombay, K.R. Ramanathan, Director, Physical Research Laboratory, P.J. Rodgers, Director General Overseas Communications Service, Bombay. INCOSPAR truly became an umbrella organization for all space related activities. “All the members of this committee are well and favorably known in the US” said Ernest C. Watson, Scientific Attaché at the American Embassy in New Delhi.⁹⁴

While the INCOSPAR was being constituted the UN Committee on the Peaceful Uses of Outer Space (UNCPUOS) had passed a resolution recommending and sponsoring the creation and use of sounding rocket launching facilities especially in the equatorial regions in the southern hemisphere. Taking the cue from the UN, a possible site in Southern India was discussed by the Indian scientists along with NASA. To help in the identification, NASA forwarded volumes of the Wallops Island handbooks, and Frutkin communicated to Bhabha his willingness to host Indian representatives at Wallops for additional discussions and/or to send NASA representatives to India for “possible assistance there in problems relating to site selection and instrumentation.”⁹⁵

Frutkin noted in 1963 that the “true potential of sounding rockets as a scientific tool can be realized only if many vertical profiles are obtained –in a wide range of

⁹⁴ American Embassy New Delhi to Department of State, 2 March 1962, Central Decimal File 1960-63, RG 59, box 3112, NARA II.

⁹⁵ Memorandum Arnold Frutkin to Homi J. Bhabha, Secretary Department of Atomic Energy, undated, “Space Cooperation with India,”(undated), RG 59, General Records of the Department of State, Special Assistant to the Secretary for Energy and Outer Space, Records Relating to Atomic Energy Matters 1944-63, box 250, NARA II.

localities and epochs – with correlation of the results. International cooperation is obviously an essential ingredient for sounding rocket work.”⁹⁶ Cooperative launchings of sounding rockets took place in many countries with shared responsibility from the host countries –mainly ground instrumentation and data analysis.⁹⁷

Sarabhai saw the importance of sounding rockets for upper atmospheric studies but also recognized the importance of ground facilities

In the field of study of our environment, one of the most important areas is the ionosphere which ranges from about 40 kilometers to about 200 kilometers, an area which is not accessible to balloons and which is below the operational altitudes at which satellites can operate. It is this area which is most importantly covered with sounding rockets. As one knows very well, sounding rockets can only perform if ground facilities and basic back-up are available. The study of this region in the equatorial areas is one of the major gaps in the study of our environment today. And so, as far as India is concerned with the facilities that have grown up, we have fantastic opportunities in the years to come to understand many complex phenomena involving the interaction of the ionosphere with the geomagnetic field, problems of the neutral and the ionized atmosphere and the interaction of these two. These subjects are of importance not only for the understanding of radio propagation, but also from the point of view of meteorology and basic problems of energy and momentum transport into the lower atmosphere where climate is made.⁹⁸

A joint scientific experiment to explore the equatorial electro-jet⁹⁹ and upper atmosphere¹⁰⁰ winds from the geomagnetic equator were incorporated in a Memorandum

⁹⁶ Arnold W. Frutkin, “Progress in International cooperation in Space Research,” *NASA News Release*, May 23, 1963, p.5.

⁹⁷ Arnold W. Frutkin, “The United States Space Program and its International Significance,” *The Annals of the American Academy of Political and Social Science* 366 (July 1966): 89-98.

⁹⁸ Ibid.

⁹⁹ The equatorial electro-jet is an electrical current at an altitude of 90-100 kms in the ionosphere and flowing along the magnetic equator in the sunlit portion of the earth from west to east. It measures about 100 to 200 kilometers in width, centered on the geomagnetic equator. The electro-jet was studied by means

of Understanding (MoU) between the NASA and India's Department of Atomic Energy on 11 October, 1962.¹⁰¹ Also, at the bureau of Near Eastern and South Asian Affairs (NEA/SAO), T. Eliot Weil, from the State Department stated that "NEA/SAO believes that it is politically desirable to have cooperative arrangements with India in the field of space science research provided such arrangements do not require exchange of classified information or material. Moreover, Indian scientists are well qualified to participate in space science and other advanced research. Such cooperative arrangements will help maximize the orientation of these scientists toward the US and away from the Soviets in the advanced application of science."¹⁰²

Under the agreement, NASA provided nine Nike Apache sounding rockets, launcher, trailer mounted telemetry receiving station, trailer mounted DOVAP tracking system, a trailer mounted MPS-19 radar with 016 computer and 70 KVA diesel generators, a Judi-Dart launcher insert, K-24 cameras for vapor cloud photography, tracing and telemetry equipment and ground instrumentation on a loan basis.¹⁰³ Before the rocket launch could happen, a site has to be chosen near the geomagnetic equator in India.

of a rocket magnetometer designed to determine the geographic location, height and intensity of the electro-jet during the period when the eleven year cycle of solar activity was near its minimum. The magnetometer permitted the observation of changes in the vertical structure of the electro-jet at different times during the day, at different times during the lunar cycle, and during various degrees of magnetic disturbance, particularly at the sudden commencement and during the initial phase of a magnetic storm.

¹⁰⁰ Exploration of the upper atmosphere winds was conducted by optical observation of sodium vapor released from a rocket payload. The object of the sodium vapor experiment was to measure upper atmospheric winds by photographing, from the ground, a cloud of sodium vapor released from the rocket and illuminated by the sun.

¹⁰¹ A supplementary Memorandum of Understanding was signed between DAE and NASA on July 1, 1965 for the collaboration in scientific investigations of the upper atmosphere and equatorial electrojet and in the measurement of electron and ion densities and Lyman alpha and x-ray flux in the D region. See, Government of India, *DAE Annual Report, 1965-66*.

¹⁰² T. Eliot Weil to Wreatham E. Gathright, October 5, 1961, "Proposed Visit of Dr. Homi J. Bhabha," folder Cooperative Space Program, box 250, NARA II.

¹⁰³ *News Release*, National Aeronautics and Space Administration, Release no 63-5, January 14, 1963, NASA Historical Reference Collection, Washington DC.

Arnold Frutkin was willing to offer expert advice on site selection if Sarabhai wished NASA received a letter on July 12, 1962 from Sarabhai requesting that a representative come to India for final selection of the proposed sounding rocket launch site.¹⁰⁴ The directions for choosing the right place came from NASA. Robert L. Krieger, Director of Wallops Station gave directions for choosing a site -- accessibility of the site to persons who are visiting the land through land, air, and sea communications, adequate telecommunication facilities, residential accommodation for the permanent staff near the launch site and also for visiting scientists.

Existing literature only highlights the role played by the Indian pioneers in the selection of this site. However, United States State Department papers show the active participation of scientists from NASA who sent volumes of materials and personnel for selecting a site.¹⁰⁵ Along with the hard labor of Eknath V. Chitnis, MIT graduate and Secretary of INCOSPAR, who was put in charge of choosing a site, one can see the active participation of scientists R.G. Bivin, Jr., (Office of International Programs) Robert Duffy, and Lawrence Cahill of University of New Hampshire (in affiliation with NASA magnetosphere experiments), in the selection of Thumba and their close relationship with Vikram Sarabhai.¹⁰⁶

Between July 16 and August of 1962 E.V. Chitnis and others made an extensive survey of the land on the Kerala coast for a suitable location in the neighborhood of

¹⁰⁴ Memorandum, State Department to American Embassy, New Delhi, RG 59, General Records of the Department of State, Special Assistant to the Secretary for Energy and outer space, Records relating to Atomic Energy matters, box 250, NARA II.

¹⁰⁵ For the Indian contribution see, R.D. John, "Some Reminiscences on Space Construction Programme," Vikram Sarabhai Archives, Ahmedabad.

¹⁰⁶ Memorandum Richard Barnes to Robert Packard, June 29, 1962, "NASA/INCOSPAR Cooperative Program," RG 59, box 250, NARA II. For more on Duffy and Cahill's activities in site selection see Memorandum, Sidney Sober, American Consul, to Secretary of State, 14 August 1962, "Proposed Collaboration between India and NASA in launching of Sounding Rockets near Geomagnetic Equator" RG 59, box 3112, NARA II.

major towns -- Cochin, Allepy, Quilon, Trivandrum, or Cape Comorin (now Kanyakumari). These are the places that were visited: Allillathura, Perumathura, Thumba Punathura, and Varkala. After this initial survey, the final meeting took place at PRL. Bivins, Cahill, R.T. Duffy, K.R. Ramanathan, V.A. Sarabhai, P.D. Bhavsar, EV Chitnis narrowed the choice down to Thumba.¹⁰⁷ However, Thumba was a compromise location. Actually, the magnetic equator passes through a place called Quilon, 32 kilometers away from Thumba but owing to safety issues and the number of people to be relocated, experts from NASA and India after surveying the Kerala coast upto Kanyakumari, the southern tip of India, finally chose Thumba.¹⁰⁸

Thumba

A few miles away from the town of Trivandrum is a place called Thumba. The place in Malayalam denotes a foot shaped white flower measuring a couple of centimeters. The herbaceous plant *Leuca Indica* belonging to the family Lepidaceae is ubiquitous in the Kerala. This flower is most coveted during the *Onam* festival, celebrated all around the state, for floral formation (*athapoo*). What was once a quiet

¹⁰⁷ R.G. Bivins Jr. Office of International Programs NASA to Secretary of State, "Meeting regarding NASA/INCOSPAR Program at Physical Research Laboratory, Ahmadabad, August 5-6 NASA," August 7, 1962, RG 59, Scientific Research and Development, box 258, NARA II.

¹⁰⁸ Ezhudeson, a village in Vilavancode Taluk of Kanyakumari District of Madras State, 20 miles south of Trivandrum port, was very much liked by E.V. Chitnis -- Secretary of INCOSPAR. He made visit to that village on July 20, 1962. The site was hinted to Chitnis by K. Janardhanan Nair, Tahsildar of Neyyattinkara, whom he met along with Theyyunni Nair, Revenue Divisional Officer, Trivandrum District on the same date. K Sukumaran Nair, Compost Inspector, and brother of Narayanan Nair, who was Technical Assistant at Cosmic Ray Out Station of Physical Research Laboratory at Trivandrum, took Chitnis to Ezhudeson village. Chitnis was impressed by the place, "it is, in my opinion, the best place, the most extensive vacant place seen so far," The site has an ideal terrain, has single phase electric supply, good roads, ideal terrain, and the major point for Chitnis is that the place is in Madras State and acquiring this land will not pose a problem. Acquiring land in Kerala State is a "big problem" and could "cause delay" he said. Too impressed with the site, he asked K. Sukumaran Nair to provide him the sketches and details about the place. E.V. Chitnis, "Mission: Preliminary Survey for the Rocket Launching Site: Report on informal and unofficial visit paid to site 'Ezhudeson' in Vilavancode Talkuk of Kanyakumari District of Madras State, on July 20, 1962," folder 14.B Outer Space, June-December, 1962, General Records of the Department of State, Special Assistant to the Secretary for Energy and Outer Space, Records Relating to Atomic Energy Matters, 1944-63, Scientific Research and Development, box 258, NARA II.

coastal fishing village was transformed in the early nineteen sixties into an international sounding rocket facility. Its southern location ($8^{\circ} 33' \text{ N}$, $76^{\circ} 56' \text{ E}$) close to the magnetic equator ($0^{\circ} 24' \text{ S}$) was chosen by a team of experts for launching sounding rockets to undertake geophysical investigations, particularly those dealing with the interaction of neutral and charged particles in earth's magnetic field.

The importance of the geomagnetic equator for geophysical studies was earlier noted by the British. Through close collaboration with Rama Verma, the Raja of Travancore, John Coldecott, an astronomer and a commercial agent to the Travancore Government, built an observatory in Trivandrum in 1837. The observatory was equipped with a "transit instrument by Dollond, two mural circles, and equatorial, altitude and azimuth, and magnetic and meteorological instruments." Coldecott was succeeded by Spersneider and then by John Allan Broun who was the director of the observatory from 1852-1865. It was Broun who made "hourly magnetic observations simultaneously at three different stations, relative especially to the diurnal variation of magnetic declination." Sarabhai after the establishment of TERLS said "it is now more than a hundred years since the British scientist Allan Broun, with the Indian assistants, made his important contribution to geomagnetism diurnal variations of the magnetic declination at Trivandrum near the magnetic equator one can safely predict that with the commencement of the space activities at Thumba during November 1963 many new and important scientific discoveries will once again originate from research in this area."¹⁰⁹

¹⁰⁹ Markham, Clements R. *A Memoir on the Indian Surveys* (London: W.H. Allen and Co, 1871), pp. 243-244. Vikram Sarabhai, "Significance of Sounding Rocket range in Kerala," *Nuclear India* (December 1963).

Kerala is a new name given to the princely state of Travancore state. And it is radioactive , by that I mean, it has rich deposits of Monazite ore from which Thorium could be extracted. Experts from Britain, Canada, France and US often visited this place for shipping the ore to their respective countries. Communism and monazite deposits and the need to challenge the Soviets with the openness of their space endeavors prompted the US and Indian experts to narrow down on Thumba. The choice of place was not geographically determined, as often mentioned in the literature on the Indian space program, but geopolitics also played a part.

Once the site was selected, detailed planning started for establishing a launching station. For civil constructions, an engineer from the Department of Atomic Energy, R.D. John was chosen by C.M. Goveas, Chief Engineer, Atomic Energy Establishment, for the task. Goveas was impressed with John's work in the building of irrigation dams and construction of buildings in the Madras Engineering Service. "As the job seemed to be new, interesting and challenging, I agreed," said John. Chitnis who would accompany John to Thumba, explained the project in detail, and handed him a "one page project report" with all the tasks (launch pad work, telemetry and DOVAP pads, substation and Block house) to be completed with a budget of 15 lakhs of rupees. On 14th January 1963, while waiting at the Bombay airport to catch a flight to Trivandrum, Sarabhai briefed John and Chitnis about the importance of the project and he requested John to finish the project in "shortest possible time." This was John's first meeting with Sarabhai, "his simplicity, casual dress and crisp language appealed to me greatly. I developed an instant regard for him," said John.¹¹⁰

¹¹⁰ R.D. John, "Some Reminiscences on Space Construction Programme," Vikram Sarabhai Archives, Ahmedabad, India.

At Thumba, the land acquisition went smoothly. John had good access to Kerala government officials; the Chief Secretary, Finance Secretary provided all the help they could for swiftly establishing the facility. The total land area of 550 acres was inhabited by fisher folk belonging to catholic Christians and central to the village was a St. Mary Magdelene Church (which was later used as a shed for rocket assembly). With the help of District collector Madhavan Nair, and with the financial assistance from DAE, State Government and funding from the catholic bishop the people at Thumba were relocated to “Pallithura.” The “Thumba Project”, as it was called then, also provided jobs for the unemployed youth of Kerala. By February 1963, John had all the glitches cleared and was ready to begin the construction work. While Thumba was being made ready a team of Indian scientists were sent to Wallops (see below), and they provided more details on the construction of a sounding rocket facility (based on the facility at Wallops). All of the main construction was completed in October 1963.

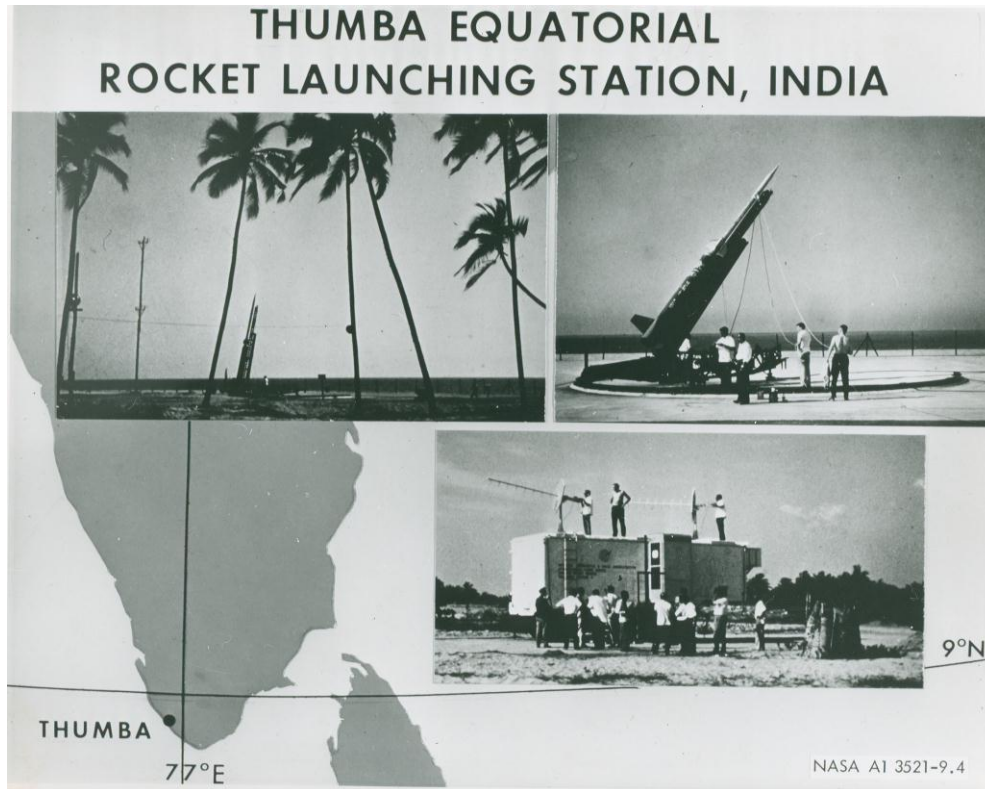


Figure 5: Thumba Equatorial Rocket Launching Station (TERLS)

Source: NASA.

Site selection was just the first step. Beyond this there are various technological hurdles in establishing a sounding rocket range for launching and retrieving data from the sounding rocket payload. To ease the difficulties the MoU between NASA and INCOSPAR included a provision for the recruitment of a small group of young men affiliated with INCOSPAR to visit NASA for training at the Goddard Space Flight Centre, and at the Wallops Island facility, where they would learn about building and launching sounding rockets. This whole arrangement was in accordance with Frutkin's guidelines for international cooperation and there was no exchange of funds. India paid for the travel and subsistence of its trainees. The training was only in assembling imported sounding rockets and their scientific payloads, procedures for the safe launch of

these rockets, tracking the flight of the rockets, receiving data radioed down during flight and collecting other scientific information. Initially, eight Indian representatives appointed by INCOSPAR were trained at NASA field centers for approximately six months in preparation for operations at the Thumba Range.



Figure 6. NASA Wallops Station, June 7, 1963 – INCOSPAR Trainees examine a K-24 Camera. This camera was used for photographing sodium vapor cloud experiments. Left to right: B. Ramakrishna Rao, A.S. Prakasa Rao, Pramod Kale, R. Aravamudan, H.G.S Murthy. (Source: NASA)

Pramod Purushotam Kale was one of those handpicked by Sarabhai and sent to NASA facilities for training in sounding rocket assembly and launch. I had the opportunity to meet him at his residence in Pune on January 2009. Pramod Kale was born in Pune and did most of his early education in Ahmedabad and in Baroda (now Vadodra). He completed his B.Sc from Ferguson College, Pune and while pursuing his Masters in Electronics he talked to Vikram Sarabhai and joined the Physical Research Laboratory to get practical training. It was here that he would begin his early work on tracking explorer satellites through the microlock station that NASA donated. After his Masters training he joined PRL in 1962. He vividly remembers the contributions made by PRL during IGY and how PRL was become a Mecca for cosmic ray and upper atmosphere research and a space hub within the Department of Atomic Energy.

In the month of January, 1963 he visited the Sounding Rocket Division of Goddard Space Flight Center (GSFC) which was then located at Beltsville industrial complex. It was here he learnt about rocket launching, payload assembly, range safety, tracking the rockets using Doppler velocity and angle tracking. His chosen area of expertise was in the “Range Timing System.” On their return in July 1963, the team would set up the sounding rocket range in Thumba. Subsequently, there was a constant traffic of scientists and engineers, in batches, from India to NASA facilities during the 1960s.



Figure 7. November 5, 1963: Indian and Pakistan nationals loading Judi-Dart into launcher. This is a part of their training in launching meteorological rockets in connection with the IIOE. Left to Right: D. Eashwardas, Indian Trainee and Salim Mehmod, Pakistan trainee. (Source: NASA)

Nike Apache Rocket launch - November 21, 1963

The first rocket launch from TERLS was a historic moment. Even today the date is marked as the launch date of India's space program. Kale recalls the first launch as a great success and a lot of planning went toward achieving the feat. The entire sounding rocket system was loaned by NASA and the payload was provided by the French national space agency, the Centre National D'Etudes Spatiales, through J.E. Blamont. The objective was to launch a Nike Apache sounding rocket two minutes after sunset, photographing the sodium vapor release in the twilight sky using special cameras donated by NASA. The cameras were placed in four different locations and photographed

simultaneously from Cape Comorin, Palayamcottah, Kodaikanal and Kottayam.¹¹¹ The purpose of releasing the payload was to get detailed knowledge of the “wind system above 80 km of the earth’s atmosphere.” Though recordings were done at different latitudes no data was collected on the geomagnetic equator so the scientists found the new location at Thumba to be conducive for the study of “hydrodynamically and hydromagnetically controlled motions in the equatorial thermosphere, which will ultimately lead to a better understanding of the process taking place in the thermosphere as a whole.”¹¹²



Figure 8. Geographical location of camera sites and launch sites¹¹³

I have always wondered why NASA did not provide the payload and why the Indians were asked to seek help from Blamont of France? All published sources on the maiden launch of Nike Apache never questioned how or why the French were involved.

¹¹¹ A K-24 type camera was used in all four locations to take the photographs. The camera was equipped with Tri-X Kodak panchromatic films and Wratten 23 A type filters.

¹¹² P.D. Bhavsar and K. Ramanujarao, A First Study of Atmospheric Winds Near the Equatorial Electrojet by Sodium Cloud Technique, *International Space Science Symposium*, 5th, Florence, May 12-16, 1964, *Space Research* 5, (1965): 986-996.

¹¹³ Ibid

The reason, apparently, was that India did not have enough foreign exchange to get the payload from NASA. The MoU for the November launch was drafted in the Spring of 1962 and at that time the nascent Indian space establishment did not have the infrastructure to assemble a payload, so Sarabhai sought help from NASA. Arnold Frutkin, because of NASA guidelines, requested Sarabhai to get help from Jacques Blamont of France for the payload.¹¹⁴ P.D. Bhavsar of PRL along with Blamont worked on the payload to be fixed on the Nike Apache rocket. The foreign exchange problem also became a hurdle for Sarabhai to pay subsistence for the trainees in the US. So he broached the subject with Frutkin and asked whether a “reciprocal funding agreement” would be possible – which is, INCOSPAR will pay NASA personnel visiting India at US per-diem rates, and NASA would pay for Indian personnel at Indian per-diem rates. NASA agreed to the “reciprocal funding agreement”¹¹⁵

The Rocket Launch

The mood was tense at Thumba that evening. Homi Bhabha was at the block house at TERLS asking many questions to the engineers about the sounding rocket launch. Vikram Sarabhai was not at the launch site. He was at the nearby beach along with Governor of Kerala and other government representatives and dignitaries to view modernity displayed by the orange trail of sodium vapor. Arnold Frutkin was at the launch site along with Ed Bissel, NASA head office, Robert Conrad, Jacques Blamont,

¹¹⁴ Jacques Blamont was a product of the French university system. Well known in NASA space science circles, he had extensive experience with sodium vapor payloads both with the Javelin sounding rockets and also with the French Veronique sounding rockets. NASA officials introduced Blamont to Sarabhai. Blamont would become a trusted friend of the Indian space establishment. For more on Blamont and his contributions see John Krige, Angelina Long and Ashok Maharaj, *Conquest and Collaboration*, (forthcoming) Chapter 2: NASA, Space Science and Western Europe.

¹¹⁵ R.G. Bivins Jr. Office of International Programs NASA, meeting regarding NASA/INCOSPAR Program at Physical Research Laboratory, Ahmedabad, August 5-6, August 7, 1962, RG 59, box 258, NARA II.

Richard Barnes, J.F. Bedigner of the Geophysical Corporation of America, Howard Galloway, engineer at GSFC and Indian scientists.¹¹⁶

Precisely at 6:23 pm, the rocket streaked into tropical space and released the payload at an altitude of more than eighty kilometers. There was excitement and jubilation in Kerala and the neighboring state of Tamil Nadu. Seeing the launch Bhabha made the comment “In reality NASA launched our space programme”¹¹⁷ and Sarabhai remarked, “with the firing of a rocket, for the first time in India, on November 21 from Thumba, Near Trivandrum, India has entered the Space Age, even though on a modest scale.”¹¹⁸

¹¹⁶ The first launch of Nike Apache was vividly narrated by Pramod Kale. Ashok Maharaj interview with Pramod Kale, January 2009. <http://www.hinduonnet.com/fline/fl2101/stories/20040116004011600.htm> (accessed on 20 February, 2011)

¹¹⁷ “We have Joined Space Club: First Rocket Fired Successfully, Research Centre in 18 Months,” *Times of India* (22 November 1963), p-1.

¹¹⁸ Vikram A. Sarabhai, “Significance of Sounding Rocket Range in Kerala,” *Nuclear India* (not dated)

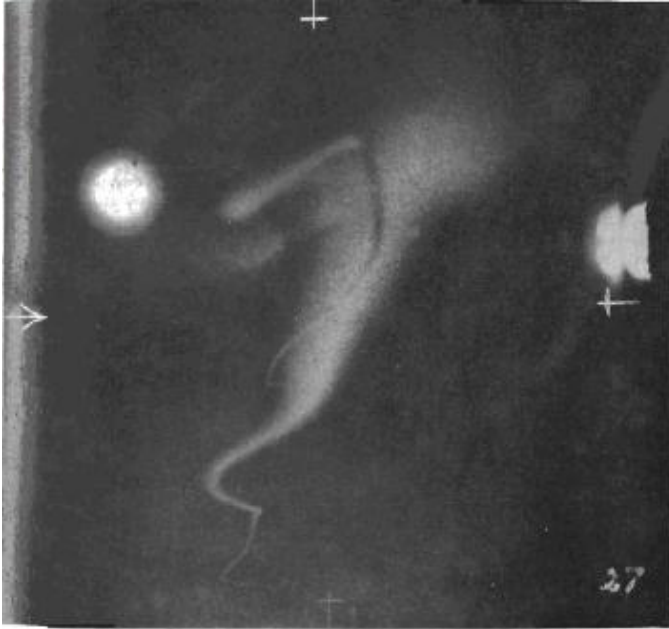


Figure 9. Photograph of sodium vapor cloud taken 500 seconds after the rocket launching, Palayamkottai, 21 November 1963.¹¹⁹

What began as a “bilateral Indo-American launching facility” at TERLS evolved into an international facility, a productive site where different countries, in spite of their political differences, could join together for promoting the peaceful uses of outer space. The main scientific motivation for Frutkin to cooperate in a sounding rocket program was the perceived benefit of getting scientific data of the tropical atmosphere. He also believed that it would “particularly welcome Soviet participation, which might lift some of the veil of secrecy from Soviet space activities.”¹²⁰ Apart from the United States, the Soviet Union and France also gave hardware for the establishment of TERLS. Under a collaborative agreement with the Centre National d' Etudes Spatiales of France, TERLS received Centaur sounding rockets for experiments to measure upper atmosphere winds, a

¹¹⁹ P.D. Bhavsar and K. Ramanujarao, A First Study of Atmospheric Winds Near the Equatorial Electrojet by Sodium Cloud Technique, *International Space Science Symposium, 5th*, Florence, May 12-16, 1964, *Space Research* 5, (1965): 986-996

¹²⁰ Memorandum, Sidney Sober, American Consulate, to Secretary of State, 14 August 1962, “Proposed Collaboration Between India and NASA in launching of Sounding Rockets near Geomagnetic Equator,” RG 59, box 3112, NARA II.

Centaur launcher, Bourdereau Camera, and Cotal LB radar for tracking the rockets. This instrument enabled the automatic tracking of rockets in flight up to a range of 300 km, and provided the accurate polar coordinates in the form of analogue signals. Equipment for measuring the temperature of the sodium cloud, and a ground console for a TMA rocket payload was also provided. The Soviet Union through the Hydrometrological Services (HMS) donated a Mi-4 range recovery helicopter, a shaking table for preflight tests and a Minsk-II electronic computer.¹²¹

Historically viewed, NASA took the initial steps to make the sounding rocket range into an international one under UN auspices. Arnold Frutkin approached Vikram Sarabhai to offer TERLS to international participants and to seek UN sponsorship. A resolution was later introduced by the United States into the Technical Subcommittee of the United Nations Committee on the Peaceful Uses of Outer Space for UN sponsorship of sounding rocket ranges in “scientifically critical locations,” and to encourage other countries to use the facility.¹²² COSPAR was also looking for the creation of an equatorial sounding rocket launching facility for two major international programs - the International Indian Ocean Expedition (1962-1967) and the International Quiet Sun Year (1964-65); India offered the sounding rocket range for international use for peaceful space research.¹²³ Sarabhai decided to open the facility and told Frutkin that “you will be glad to learn that India has decided to extend an invitation for the location of a U.N.

¹²¹ *Handbook for Range Users*, Thumba Equatorial Rocket launching Station, Indian Committee for Space Research, July 1967, p. 111. For an excellent coverage on the technology accumulation in ground systems see Angathevar Baskaran, “Technology Accumulation in the Ground Systems of India’s Space Program: The Contribution of Foreign and Indigenous Inputs,” *Technology in Society* 23, no. 2 (2001): 195-216.

¹²² See Arnold Frutkin, *International Cooperation in Space* (Englewood Cliffs, N.J.: Prentice-Hall, 1965), p. 62.

¹²³ The wind patterns of the monsoons in the Indian Ocean merit close study, not only because they give striking evidence of interactions between the ocean and the atmosphere but also because of the possible influence of the sun’s particulate radiation on the earth’s weather as noted in Victor K. McElheny, “India’s Nascent Space Program,” *Science* 149 (September 1965): 1487-1489.

equatorial launching facility in India, on the lines of the recommendations made at the Geneva meetings of the Scientific and Technical Subcommittee of the U.N Committee on the Peaceful Uses of Outer Space.”¹²⁴ R. Shroff, Deputy Secretary, Department of Atomic Energy, Government of India said that “if the United Nations accepts the offer, it is our intention that the launching facility to be set up in collaboration with NASA should be dovetailed into the international facility.”¹²⁵



Figure 10. The Indian launch crew mates the Apache rocket to the Nike booster in preparation of a launch from Euqatorial Sounding Rocket Range at Thumba, India, located near the Geomagnetic Equator. The rocket was launched cooperatively by NASA and INCOSPAR, and reached an altitude of 104.5 miles. The payload comprised of a magnetometer and a Langmuir Probe, to determine the altitude and intensity of electric current systems in the ionosphere. (Courtesy, NASA)

¹²⁴ Memo Vikram Sarabhai to Frutkin, July 12, 1962, RG 59, General Records of the Department of State, Special Assistant to the Secretary for Energy and Outer Space, Records Relating to Atomic Energy Matters 1944-63, box 250, NARA II.

¹²⁵ Memorandum, R. Shroff, Deputy Secretary, Department of Atomic Energy, Government of India, to Arnold W. Frutkin, July 28, 1962, RG 59, General Records of the Department of State, Special Assistant to the Secretary for Energy and Outer Space, Records Relating to Atomic Energy Matters 1944-63, box 250, NARA II

In January 1964, a team of scientists appointed by the UN committee made an inspection visit to TERLS to determine its compliance with the condition of sponsorship. The team concluded that TERLS met the requirements for an international sounding rocket facility which had been set forth by the Committee, and recommended UN sponsorship for TERLS. TERLS received UN sponsorship in 1965. Vikram Sarabhai years later mentioned that “the sponsorship of TERLS by UN is not simply formal; it constituted an umbrella under which above 105 rocket experiments were conducted by various nations like France, Germany, Japan, United Kingdom, USA and USSR, jointly with India as an example of active co-operation in space research.”¹²⁶ So it is clear that the push for making TERLS international as stated above came both from NASA and from the nascent space team at INCOSPAR. Since India’s independence, the UN was seen as a node for negotiating international collaborative activities. Some of the sounding rockets that were launched during this period were: Nike Apache, Centaure, M 100, Skua Patrol, Boosted Arcas, Dragon and Judi Dart.¹²⁷

After the UN sponsorship an International Advisory Panel was formed by selecting two representatives from India, the United States, USSR and France to continue operations. This aspect is direct evidence that points to Sarabhai’s interest in international cooperation. The formal dedication of TERLS to the UN occurred on 2nd February 1968 with the presence of various dignitaries including Arnold Frutkin, Leonard Jaffe, Director of Space Applications programs, Office of Space Science and Applications. The meeting was presided by Prime Minister Indira Gandhi.

¹²⁶ Vikram Sarabhai, et.al., *Application of Space Technology to Development* (A study prepared for the UN, 1970), p. 1.42.

¹²⁷ Government of India, Department of Space, *Annual Report 1980-81* (New Delhi: Government of India Publications, 1982), p. 13. For a complete list of sounding rockets launched until 1972 see table 2 at the end of this chapter.

The Limits of US Cooperation

The sounding rockets provided by NASA during the early sixties were “low-end” declassified scientific instruments. When NASA wanted to provide advanced sounding rockets the State Department expressed strong reservations. The case of the transfer of Arcas sounding rockets for the International Indian Ocean Experiment (IIOE) throws light on the sensitiveness of donating advanced sounding rockets. IIOE involved multinational sounding rocket experiments at various points in the Indian Ocean region for “intensive and coherent investigation of an ocean atmosphere regimen.” NASA wanted to organize this joint experiment in cooperation with the National Academy of Science, the U.S. Weather Bureau and the American Coordinator for Metrology in the IIOE. As a multinational effort NASA wanted India and Pakistan to participate and NASA was willing to provide Arcas sounding rockets, the rocket suitable for IIOE, to India. Problems soon emerged. The Atlantic Research Corporation manufactured the Arcas rockets for the Navy and they classified the technology as “confidential.” Providing these rockets to Pakistan did not cause any problem because, as we pointed out earlier, Pakistan was a preferred ally of the U.S., and a diplomatic framework was in place to enable the transfer with appropriate guarantees. But there was no such framework for dealing with India -- and Frutkin felt that it would be “awkward to conduct an Indian Ocean program without the participation of India.” He cited the visit of Prime Minister Nehru to the U.S. in the fall of 1962 and specifically mentioned the joint statement issued by President Kennedy and Prime Minister Nehru that indicated that space cooperation was among the areas of US/India relationships that were discussed. He went on to find alternative arrangements for giving India the Arcas sounding rockets



Figure 11. Arnold Frutkin seated behind Indira Gandhi Source- The Hindu

either by “declassification of Arcas or by provision of the classified Arcas under suitable waivers and guarantees.”¹²⁸ When TERLS became operational with the launching of foreign sounding rockets Vikram Sarabhai actively sought to advance the field by nurturing the development of space technology in India incrementally. Needless to say, without external assistance and training it would have been extremely difficult for India to have managed to build a sounding rocket program at this early stage. In the early 1960s, when rockets had attained the capability of launching satellites, Sarabhai was still developing small sounding rockets. This effort has to be understood within his larger picture of developing a nucleus of capable scientists and technologists around the essentials of rocketry, which would eventually help India if a path was taken to indigenize launch vehicles. Sarabhai noted that “when a nation succeeds in setting up a scientific program with sounding rockets, it develops the nucleus of a new culture where a large group of persons in diverse activities learns to work together for the accomplishment of a single objective.”¹²⁹

¹²⁸ Confidential memorandum, Frutkin to Philip Farley, Department of State, Jan 18, 1962, “Arcas for India,” RG 59, folder Cooperative Space Program, box 250, NARA II. A boosted Arcas was flown from the Thumba Range for scientific studies, see Table 2 at the end of this chapter.

¹²⁹ Kamla Chowdhry, *Vikram Sarabhai Science and Development*, p. 25

For charting a course on the indigenous production of sounding rockets, India first started to produce a stable sounding rocket under license. The natural choice was to approach NASA for technology transfer of a sounding rocket. However, NASA's guidelines for cooperation allowed no room for technology transfer or license production. The Arcas sounding rocket case, discussed earlier, further pointed to the sensitivity of the issue when it came to dealing with India. With no help from NASA, India relied on France. The French firm Sud-Aviation signed a licensing agreement with the Department of Atomic Energy for manufacture by India of two stage Centaur rockets --frames, propellant and electronic instrumentation -- at the DAE establishment at Trombay.

After licensed production the road toward the fully indigenous production of sounding rockets and complementary subsystems – scientific payloads, instrumentation, telemetry and ground systems -- was started. As a result of this conscious attempt, Thumba during the early sixties witnessed the transnational traffic of experts – scientists, technologists and engineers; and the mushrooming of new firms, facilities and institutions. After TERLS was established Sarabhai and the nascent space establishment contacted the Kerala state to extend the facility. In the year 1965, 40 acres land was procured on Veli Hill for establishing a Space Science Technology Center (SSTC), additional land was procured in Valiamala in Kerala and Mahendragiri in Tamil Nadu.

At Veli Hill the SSTC laboratories, workshop and offices, hostels, administrative buildings, were constructed. Sarabhai also recruited Indian engineers and scientists from the USA, France and Germany who were either pursuing their degrees or involved in space related research activity, Chief among them are Y.J. Rao, A.E. Muthunayagam, Vasant Gowarikar, D.S. Rane, S.C. Gupta. They would lead key departments in the

newly formed SSTC. (See chapter 3). For the indigenous production of rockets and complementary systems the following facilities were started at SSTC: Rocket Propellant Plant (RPP), 1969; Rocket Fabrication Facility (RFP), 1971 and Propellant Fuel Complex (PFC). The indigenous production of sounding rockets was gradually scaled up to a satellite launch vehicle. When planning began for building a four stage satellite launch vehicle, a launch complex called Sriharikota Range (SHAR) – Latitude, 13 degree 47'N, longitude 80 degrees 15' E), was built on the eastern sea coast, in the state of Andhra Pradesh. Y.J. Rao, after his initial assignment as the Project Director of the SLV-3 rocket, was posted by Satish Dhawan to develop the SHAR range. Being a native of Andhra Pradesh himself, his language abilities and organizing capabilities were critical for his appointment to head the planning of SHAR. He slowly transformed the isolated village inhabited by Yandi tribes into a high tech enterprise (Chapter 3 details the establishment of SHAR and the contributions of Y.J. Rao). At SHAR a number of facilities were built, the important ones being the Solid Propellant Space Booster Plant (SPROB), and the Static Test Evaluation Complex (STEX) for testing rocket stages manufactured at SPROB, as well as tracking and telemetry equipment.

Parallel skills were also acquired in satellite technology. A step in the direction of participating in the evolving global satellite communications system was taken through the establishment of the Experimental Satellite Communication Earth Station (ESCES) by INCOSPAR in Ahmedabad with assistance from the United Nations Development Program (UNDP) through the International Telecommunication Union (ITU) – the executive agency of the project. The equipment came from National Electronics Corporation (NEC) of Japan. Through an agreement with NASA this earth station

participated in the Application Technology Satellite (ATS-2) Test Plan. ESCES was also foreseen by officials at NASA, the UN, and INCOSPAR as a node for training scientists and engineers from several developing countries in the field of satellite communication and related technologies.¹³⁰ With the growing potential of application satellites, a dedicated Space Applications Center (SAC) was established in Ahmadabad, and it housed the following facilities – ESCES, Satellite Communications system division (SCSD), Remote Sensing and Meteorological Applications Division (RSMAD), Electronics Systems Division, (ESD), Microwave Division (MID) and Audiovisual Instructional Division (AVID). When Sarabhai became the head of India's Atomic Energy Commission, after the tragic death of Homi J. Bhabha in an air crash over Mont Blanc in 1966, he was himself thinking of how best to use nuclear power for development needs. By associating itself with the tenets of modernization the nascent space group was able to convince the Indian Government of the potential of the space program for socio-economic benefits and thereby extract financial support for their efforts.

Also, in August 1968, for the first time a concrete effort was made by the United Nations to host an international conference on the Exploration and Peaceful Uses of Outer Space in Vienna. Leading scientists from around the world attended the conference and reported about the activities carried out during the first decade of the space age and the plans for the future. For many developing countries in Latin America and in the Asian region, the “space age dawned at Vienna.”¹³¹ Founding fathers of many developing countries' space programs saw the immense promise of space science and technologies

¹³⁰ See Carl Q. Christol, “Space Joint Ventures: The United States and Developing Nations,” *University of Akron Law Reviews* 8 (1975): 398-415.

¹³¹ For more on the importance of Vienna Congress for developing countries see, Vladimir Gubarev, *Aryabhata The Space Temple* (New Delhi: Sterling Publishers, 1976).

for socio-economic development. Sarabhai was the Scientific Chairman at the conference and in his presentation he talked of the “totality about the process of development which involves not only advanced technology and hardware but imaginative planning of supply and consumption centers, of social organization and management, to leapfrog from a state of backwardness and poverty.”¹³² It was also here at Vienna that, for the first time, the benefits of remote sensing were first discussed.

The task of beginning a remote sensing program in India was first given to Raman Pisharoty. He created an awareness regarding this technology among politicians, science administrators and others. He led a team of scientists to the USA where remote sensing was being applied to agriculture, forestry, hydrology, oceanography, geology etc. Soon after his return, Pisharoty organized the first successful mission of coconut wilt-root disease eradication by remote sensing techniques using Soviet aircraft and US equipment – Hasselblad cameras donated by NASA.¹³³ Today he is regarded as father of remote sensing in India. Pisharoty’s history also shows the transnational connection that facilitated scientific exchanges in the remote sensing field. He was born in February 1909, and received his basic education at Victoria College, Palghat (1925-27) and St. Joseph’s College, Trichinopoly (1927-31). He received the B.A. Honors degree in 1931 and the MA degree in 1936 from Madras University. While employed as a Lecturer in Physics at Madras he spent several holidays as a vacation worker at the IISC at Bangalore under the guidance of C.V. Raman. In 1952, Pisharoty was sent to the US by the Government of India under a Technical Cooperation Mission (TCM) grant. After visiting

¹³² Address given as Scientific Chairman of the United Nations Conference on the Exploration and Peaceful Uses of Outer Space, Vienna, August 1968. See, Kamla Choudhary, *Vikram Sarabhai: Science Policy and National Development* (Delhi: Macmillan 1974), pp 28-37.

¹³³ For NASA’s cooperation with India in the field of remote sensing see, John Krige, Angelina Long and Ashok Maharaj, *Contest and Collaboration*, (forthcoming), Chapter 12.

the US weather Bureau offices in Washington D.C. Los Angeles, New Orleans and the Hurricane Forecast Center at Miami, he undertook post-graduate work in meteorology at the University of California, Los Angeles, under Professor J. Bjerknes. He was awarded an MA degree in 1953 and a PhD in 1954 by UCLA. He has to his credit forty six papers. His scientific papers are in the fields of microscopy, ultrasonics, elasticity, X-rays, dynamic meteorology, climatology, synoptic meteorology, weather forecasting, geomagnetism seismology and oceanography.¹³⁴

Soon after the Vienna conference, a small restructuring of the space program happened. A separate Indian Space Research Organization (ISRO), still affiliated with DAE, was formed on 15 August 1969 (coinciding with India's Independence Day). Though a separate body, PRL, Ahmadabad still acted as the nerve center of ISRO. By this time several other institutional developments had been initiated by Sarabhai and a concrete ten-year plan for future nuclear and space activities was brought out, entitled the *Profile for the Decade* (1970-1980). This forty-odd page booklet was produced by the Department of Atomic Energy –mainly Sarabhai and his cohorts. The profile stated that 'the principal objectives of the space program in India are to develop indigenous competence for designing and building sophisticated hardware involved in space technology including rockets and satellites for scientific research and practical applications, the use of these systems for providing point-to-point communication and a national television hook-up through a direct broadcast synchronous satellite, and the applications of satellites for meteorology and for remote sensing of earth resources.'¹³⁵ In

¹³⁴ From American Embassy to Department of State, May 25, 1962, RG 59, Central Decimal File 1960-63, box 3112, NARA II.

¹³⁵ For a critical view of the "profile" see Ashok Parthasarathi, *Technology at the Core Science and Technology with Indira Gandhi* (Addison-Wesley Professional, 2008).

the space research and development, the prolife provides for the building of satellites, flight guidance systems for rockets, on board miniaturized computers and high performance missile tracking radar units at Thumba; and making tests at Sriharikota with Rohini and Menaka rockets.

Vikram Sarabhai passed away suddenly on December 31, 1971 during his routine visit to Thumba. In January 1972, as an interim measure, Prime Minister Indira Gandhi appointed, Mambilli Kalathil Govind Kumar Menon, physicist at TIFR, as the Chairman of the space program. The search for a suitable leader began and two names were considered, says Ashok Parthasarathy, who was the Special Assistant, Science and Technology to Indira Gandhi between 1970-75. Rao Valluri, the director of National Aeronautical Laboratory, CSIR was one candidate; the other was Satish Dhawan, Aeronautical Engineer, who received his PhD from California Institute of Technology (Caltech), Pasadena. Dhawan was chosen because of his familiarity with the space establishment and also because he had been a member of the Atomic Energy Commission since 1968. When the choice was made by Indira Gandhi, Dhawan was at Caltech on a sabbatical. After his return to Bangalore, he sent a detailed letter to Indira Gandhi about his vision for the space program of India – his ideas of what India should pursue. The “remarkable letter” outlined a clear vision for the basic infrastructure required, application satellites both communication and remote sensing and launch vehicles. He concluded the letter by saying that “if what he had sketched out in the letter was the kind of long term program the government visualized for the country, he would be honored to head the program.” The Prime Minister gave a green signal and after extensive discussions with the cabinet ministers, and other top executives, the space program was

restructured in May 1972. A Space Commission (SC) and a separate Department of Space (DOS) were established. The space commission was composed of P.N. Haskar, strategist and policy planner in Gandhi's cabinet; T.S. Swaminathan, government official; M.G.K. Menon, Physicist TIFR; Brahm Prakash, Director of Metallurgy Group in Bhabha Atomic Research Center (BARC) and I.G. Patel (Secretary, Economic Affairs, Ministry of Finance). SC and DOS took the formal reins of coordinating all the space activities in India. Dhawan, after taking the leadership of the space program after Sarabhai's demise, asked the Space Commission to review Sarabhai's profile from the "viewpoint of appropriateness, technical feasibility, time schedules, and costs." He appointed Brahm Prakash, who just retired from BARC as the director of metallurgy to head VSSC. Prakash, received his D.Sc in metallurgy from Massachusetts Institute of Technology. Cosmic Ray physicist Yash Pal, who also received his PhD from MIT, was made director of SAC and geophysicist Devendra Lal, would head PRL. Lal was extensively involved in researching on the moon rocks donated by NASA in 1971. The whole leadership "worked as a close-knit team" for launching India into space.¹³⁶

The restructuring of the space program and revised goals pointed more toward the direction of space applications. Space sciences received less importance in Dhawan's overall program. In a seminar held between August 7-12, 1972, on space research and applications he noted that

...In the general pool of scientific knowledge, in a sense, Space Sciences and Astronomy are not really new to our culture. We need to reaffirm this in a modern sense by our activity....the group on space sciences have projected over a decade the launching of four satellites, two in each area. It is not necessary to discuss, at this stage, the merits of the experiments that have been suggested....the important question one has to ask is what is

¹³⁶ Ashok Parthasarathy, *Technology at the Core*, pp. 136-140

the minimal level which will keep the scientists abreast with developments elsewhere without excessively depleting our budget? This is one way of putting the question. On the other hand, if there are a variety of other good reasons for launching satellites and which can be justified in terms of public support, surely one can carry science piggy-back on these. What I am suggesting is that if the vehicles are in any case to be developed and satellite technology established in the country, it is not as if one is going to launch on an exclusive space sciences program cut off from the rest of all our aspirations.¹³⁷

All the space related activity carried out in and around Thumba was brought under a new center called the Vikram Sarabhai Space Center (VSSC) in 1972 and the center was placed under a Director. All activities in and around PRL were brought under the Space Application Center (SAC) in Ahmadabad. PRL which is the nerve center of all space activities, became a unit under DOS. As per Dhawan's request, the headquarters was shifted from Ahmedabad to Bangalore. An ISRO council was formed to become the "symbolic link as well as the forum for participative management between the Department which has the Government's powers and centers which execute the jobs."¹³⁸

Conclusion

The period between 1962-1972 was crucial for developing an institutional and technological base for space research in India. The growth and establishment of a domestic space program, and collaborative relationships with organizations as well as scientists and technologists in foreign lands, was due to the active interest shown by India in the field of space sciences. NASA helped the scientific elite to create bases for sounding rockets and develop institutions along the way to shaping a space program that was geared toward the development needs of the country as defined by Sarabhai. As far

¹³⁷ Report of the Seminar on Indian Program for Space Research and Applications, Indian space research Organization, August 7-12, 1972, Ahmedabad, Vikram Sarabhai Archives.

¹³⁸ Y.S. Rajan, "Management of the Indian Space Program," *Sadhana* 12, no. 3 (March 1988): 289-305.

as technological collaboration was concerned, United States assistance during the early stages of India's rocket program was limited to the donation of sounding rockets and the loaning of launchers; there was never a case of sharing the details of producing the sounding rockets locally. Homi Bhabha's request for more advanced rockets in 1965 for testing and possible technology transfer was not favored by the US. The denial of technology transfer partly explains the choice made by India to combine their own resources with help from other countries mainly, France, Germany and the Soviet Union to begin a launch vehicle program. By the time of Sarabhai's sudden demise, the *Profile for the Decade* was accepted by the Government of India, and his vision was carried further. Within a decade, incremental progress was made towards meteorological, remote sensing and communication satellites that was directed toward India's socio economic needs. His famous quote "there is no ambiguity of purpose" became the leitmotif for India's space program in the decades that followed.

Table 2: Sounding Rocket Launches from TERLS (1963-1970)

S.No	Type of Rocket	Total No. of Rockets launched from 21 November. 63 to 31 st March 1970
1	Dragon	1
2	Nike Apache*	36
3	Centaure – I	10
4	Centaure II-A	2
5	Judi-Dart*	36
6	Boosted Arcas –1*	6
7	Skua-1	10
8	Skua II (T)	1
9	Nike – Tomahawk*	3
10	Test Rocket (2.7’')	29
11	Rohini- 75	15
12	Rohini -75 Test Rocket	22
13	Rohini two –stage	1
14	Menaka I	13
15	Rohini 100	13
16	Rohini 125	2
17	Fibreglass Rocket	5
	Total	205

- Sounding Rockets provided by NASA

Chapter III

The Political and Technological Trajectory of India's First Satellite Launch Vehicle (SLV): Transnational Networks and Indigenous Efforts.

India's quest for a launch vehicle dates back to the early sixties when Homi Bhabha talked about a credible nuclear deterrent and Vikram Sarabhai wanted both to build application satellites (remote sensing, meteorology, and communication satellites) and to have the capability to launch them. But a vehicle that could carry a sizeable 'payload' materialized only after several years by incremental development beginning with sounding rockets and establishing facilities, institutions and an instrumental rationality for building a space program in a poor country along the way. As described earlier, the initial stages of India's space program were dominated by space science research. Research using sounding rockets supplied by different countries was used for extracting data through a diversity of experiments. Indigenous attempts to manufacture sounding rockets, as a step toward building satellite launch vehicles, were taken up a few years after establishing TERLS in 1962 (see chapter 2).

Soon after the Chinese nuclear test of 1964, the nascent space establishment in India negotiated with the United States for "scientific or technological spectacles" in order to regain prestige in the comity of nations in the Afro-Asian region. Bhabha and Sarabhai approached NASA and asked the agency to transfer launch vehicle technology to loft a small satellite to low earth orbit. While NASA and the United States State Department were willing to consider loaning the most sophisticated, yet to be built, geosynchronous satellite technology for developmental television, a low configuration rocket, the bare minimum to launch a small satellite, never came to fruition. Different

arms of the United States Government were divided over whether to help India with a rocket or not. Owing to geopolitical reasons and India's status as a developing country, expert assistance or technology was never transferred from the U.S. leaving the nascent space establishment to develop a launcher "indigenously."

The dilemma the United States faced in sharing launch vehicle technology was not unique to India; similar concerns were aired and stringent hurdles were imposed when selective European nations formed the European Launcher Development Organization (ELDO) to collectively build a three stage launcher called Europa.¹³⁹ Japan also faced a lot of hurdles initially when their space establishment sought assistance from the United States to build their N1 rocket based on Delta rocket technology, though here owing to political reasons limited technology was shared, with stringent controls.¹⁴⁰

When the United States was not forthcoming to help with the launch vehicle, India

¹³⁹ For a detailed discussion on ELDO and the politics of technology transfer, see John Krige, "Technology Transfer with Western Europe: NASA-ELDO Relations in the 1960s" in John Krige, Angelina Long and Ashok Maharaj, *Conquest and Collaboration: Fifty Years of NASA's International Relations in Space*, (Forthcoming). Also see John Krige and Arturo Russo, *A History of the European Space Agency, 1958 – 1987, Vol. I. The Story of ESRO and ELDO- 1958 - 1973* (Noordwijk: ESA, SP-1235, 2000), especially chapters 3, 4.

¹⁴⁰ Key arguments on the Delta technology transfer was first discussed by John Logsdon, see John M. Logsdon, *Learning from the Leader: The Early Years of U.S. Japanese Cooperation in Space*, (unpublished paper), Space Policy Institute, George Washington University, Washington D.C. Extending Logsdon's work Yasushi Sato, using Logsdon's archival collections made some interesting observations tying the transfer to the Cold War literature and offered a more nuanced understanding on the motives behind U.S. Japan space cooperation, see, Yasushi Sato, "A Contested Gift of Power: American Assistance to Japan's Space Launch Vehicle Technology, 1965-1975," *Historia Scientiarum* 11, no. 2 (November 2001): 177-204. Also of importance is Johnson-Freese, *Over the Pacific*, for her early contribution toward understanding the Japanese space program when good narratives were non-existent. For a more in depth study on the modalities of Delta technology transfer to Japan see, John Krige, Angelina Long and Ashok Maharaj, *Conquest and Collaboration: Fifty Years of NASA's International Relations in Space*, (Forthcoming).

sought help from other countries – France, West Germany and also Japan. Close interaction that was forged with France during the launch vehicle development was sustained and the two countries undertook many collaborative endeavors. West Germany also helped India with crucial subsystems like guidance and control, and launch vehicle simulation studies. Expert advice was sought from Japan and many Indian scientists and engineers also visited Japanese space facilities for training. The transnational network that was formed in the development of the SLV-3 throws light on an important fact unexplored in space history -- “Periphery – Periphery” collaboration rather than “Metropolis – Periphery” which had been the normal pattern of science and technology relations since the scientific revolution.

Existing literature on the evolution of launch vehicles generally traces the beginnings of the development of an Indian launch vehicle to 1968. However, as this story will illustrate, Vikram Sarabhai and Homi Bhabha discussed the possibility of cooperating with NASA in building a launching vehicle already in the mid-sixties, as one of several possible prestigious endeavors to regain prestige after the 16 October, 1964 Chinese nuclear test. The discussions centered on procuring the technology for the American all-solid four stage Scout rocket. Commonly called the “poor man’s rocket,” it was capable of launching satellites weighing close to 100 pounds in low earth orbit. Though initial discussions did not bear any fruit, the possibility of transferring launch vehicle technology or critical systems was not closed completely, however. NASA, not to alienate the Indian scientific elite after a close collaboration on various scientific and technological projects, had to maintain a fine balance in order to maintain the cooperative spirit between the two democracies. The prospect of sharing technology was debated

extensively at various times for close to ten years by different actors in the State Department, the Department of Defense and NASA along with their Indian counterparts. A spectrum of options ranging from outright denial to full cooperation was discussed. The geopolitical situation during the 1970s, however, did not augur well for renewed interactions between NASA and India. Positive cooperative endeavors began to wane under the vicissitudes of political relations between United States and India during the 1970s. The Indo-Pakistan war of 1971, Sarabhai's death in December 1971, and the Peaceful Nuclear Explosion (PNE) by India in 1974 all worked against close cooperation between NASA and India. United States' relations with India in space cooperation in this broader political context were relatively static, and only the collaborative endeavors agreed on in the late 1960s had any momentum.

In the light of the alienation with the United States the-then Prime Minister Indira Gandhi sought increased friendship with the Soviet Union. Two historic treaties were signed that led to the successful launch of three Indian satellites (Aryabhata, Bhaskara I, II) by the Soviet Union.¹⁴¹ Space cooperation further bloomed when Air-Force pilot Rakesh Sharma became the first Indian cosmonaut to be sent to space on a Soviet rocket in April 1984. To salvage some publicity the United States, through NASA, offered a similar position for two ISRO engineers, N.C. Bhat and P. Radhakrishnan, on its space shuttle as payload specialists for deploying the Indian Satellite, INSAT 1-C that was being built by Ford Aerospace to conduct vector control experiments. What would have

¹⁴¹ There is a real dearth of scholarship on Soviet-India space relations. For a general overview see Brian Harvey, "Russia: The Indian Connection," *JBIS* 54, (2001): 47-54, Jerome M. Conley, *Indo-Russian Military and Nuclear Cooperation: Lessons and Options for U.S. Policy in South Asia* (New York: Lexington Books, 2001); Mikhail Barabanov, "Russian-Indian Cooperation in Space," *Moscow Defense Brief* 1, no. 3 (2005): 27-31; the following book gives a detailed analysis of the close cooperation forged between India and USSR in the assembling and launching India's first satellite, U.R. Rao and K. Kasturirangan, *The Aryabhata Project* (Bangalore: Indian Academy of Sciences, 1979).

been a pinnacle of US-India cooperation in space was never achieved due to the Challenger disaster in January 1986 and the grounding of shuttle operations for the next three years.

In the event India pushed ahead and built its own, ‘indigenous’ all solid stage Satellite Launch Vehicle (SLV-3) *modeled* on Scout (see below). On 18 July, 1980 it placed a 35-kg Rohini (RS- D1)¹⁴² satellite in low-earth orbit, so becoming the sixth nation to accomplish this feat. Just as the Pokhran-I nuclear test in May 1974, exhibited the visibility of India’s nuclear program, the successful launch of the Rohini satellite (the indigenous sounding rocket was also given the same name) made the space program visible. The launch attracted global attention. The United States State Department expressed grave concern. The tense situation was only exacerbated when the Defense Department of India, seeing the successful satellite launch, enrolled Abdul Kalam, the project manager of SLV-3, to rejuvenate their ailing missile program. Kalam joined the Defense Research Development Organization (DRDO) and he orchestrated the Integrated Guided Missile Development Program (IGMDP) in 1983 that led to the organized research and development of guided missiles for different strategic military needs. Chief among those missiles was an Intermediate Range Ballistic Missile (IRBM) *Agni* which was built using the experience gained in building SLV-3. *Agni* was capable of carrying war heads close to 1000 kg with the potential to reach targets deep inside China. Kalam’s

¹⁴² Rohini (named after a Hindu goddess) was a tiny satellite in the shape of a polyhedron measuring 55 cm in height and 65 cm across and weighing 36 kg. Built at the satellite center in Bangalore, it became the first satellite to be launched in India using indigenously made rocket. It carried a multitude of instruments to analyze the performance of the launch vehicle itself, like vibration, speed, and performance of the fourth stage of SLV-3 and a tone range instrument to measure the distance of the satellite from a fixed location on earth. See *Countdown* 4, (August 1980). R.B.K. Menon, former Group Head, PPEG, VSSC was assigned the task of developing Rohini Technological Payload (RTP), see *Development of SLV-3: Retrospective* (Vikram Sarabhai Space Center: Thiruvananthapuram, 2005), p. 62.

appointment with DRDO and his development of IGMDP distressed the U.S. State Department and NASA.¹⁴³

To weave this chapter's narrative I mostly relied on material in the United States National Archives II, College Park, Md, and the NASA Historical Reference Collection, Washington D.C. From the Indian side, after much negotiation, I was able to get access to three internal SLV project reports that were brought out during the early seventies. I also got access to *Countdown*, another internal publication by Vikram Sarabhai Space Center VSSC.¹⁴⁴ Providential interviews with some of the key project leaders and personal documents shared by them greatly assisted me in filling important gaps in the evolution of SLV-3.

SLV-3 and Scout

Since SLV-3 was modeled after SCOUT, two views have dominated the historiography of its development: indigenous development and technological diffusion. The first viewpoint was expressed by scientists and engineers who orchestrated the SLV-

¹⁴³ DRDO was formed in 1958 by fusing the Technical Development Establishment of the Indian Army, Directorate of Technical Development and Defense Science Organization. What started as a small endeavor with just a handful of labs today it has more than fifty laboratories catering to the research and development of defense technologies. A nascent missile program was started even before INCOSPAR came into existence. Missile production was designated to DRDO and Defense Research Development Laboratory (DRDL) of Hyderabad. A detailed history of India's missile program has not been written so far. What is available are chapter length analysis of the origins and development. See, Timothy V. McCarthy, "India: Emerging Missile Power," in William C. Potter, and Harlan W. Jencks, *The International Missile Bazaar: The New Suppliers' Network* (Boulder: Westview Press, 1994); Dinshaw Mistry, *Containing Missile Proliferation Strategic Technology, Security Regimes, and International Cooperation in Arms Control* (Seattle: University of Washington Press, 2005). Raj Chengappa, *Weapons of Peace: The Secret Story of India's Quest to Be a Nuclear Power* (New Delhi: Harper Collins Publishers, India, 2000); Aaron Karp, *Ballistic Missile Proliferation: The Politics and Technics* (Sonia, Sweden: SIPRI, 1996), Steven M. Flank, *Reconstructing Rockets: The Politics of Developing Military Technology in Brazil, India, and Israel*, Ph.D Thesis, Massachusetts Institute of Technology, 1993; A.P.J. Abdul Kalam and Arun Tiwari, *Wings of Fire: An Autobiography* (India: University Press, 2002).

¹⁴⁴ I would like to thank Manoranjan Rao for giving me access to *Countdown* and also the Annual Reports of Department of Atomic Energy and Department of Space.

3 program. The second viewpoint comes from Western policy analysts who have denied -
- albeit without any documentary evidence -- that there was any indigenous contribution
and basically state that SLV-3 was built using the technological “blueprints” freely given
by NASA.¹⁴⁵ This interpretation of freely given “blue prints” was treated as an
established fact by various scholars who have not clearly understood NASA’s strict
policy on sharing launch vehicle technology.¹⁴⁶

A recent interview with Arnold Frutkin captures the dilemma that NASA and the
State Department faced when it came to sharing launch vehicle technology.

India came to us very early on in the mid-sixties asking for help in developing a
booster, a small booster, something like the SCOUT. There was a tremendous
debate within government as to whether to help them or not. Of course, it was
slanted by the fear that India would be using it as a [...]delivery vehicle for a
weapon. At the time, I was all for working with India on a SCOUT. I thought in
the long run India would have what it wanted by way of a delivery vehicle or a
space vehicle, and either they would have it with our goodwill and friendship or
they would have it over our dead bodies, and that was precisely what I thought at
the time. But there was great division within government and there was argument
over how long it would take India to do it on its own. Some people thought it
would be very soon and some thought it would take more, but it took a lot longer
to get to a vehicle able to deliver payload to orbit. But I think I was right in the
long run. I mean, that’s arguable. I don’t mean I’m proven right, I think I’m
right, that India resented our not working with them, and there was a long period

¹⁴⁵ Gary Milhollin, “India’s Missiles—With a Little Help from Our Friends,” *Bulleting of the Atomic Scientists*, (November 1989): 311-15. Most of the scholarship on India’s missile and space program often mention Milhollin’s piece to state that SLV-3 was built using Scout blueprints. In a testimony, before the House Committee on Science on June 25, 1998, Milhollin stated that “in 1965, The Indian Government asked NASA for design information about the Scout...NASA obligingly supplied the information. Kalam then proceeded to build India’s first rocket, the SLV-3, which was an exact copy of the Scout.” See http://www.globalsecurity.org/space/library/congress/1998_h/980625-milhollin.htm, (accessed on December, 12, 2009).

¹⁴⁶ see Richard Speier, “U.S. Satellite Space Launch Cooperation and India’s Intercontinental Ballistic Missile Program,” in Henry D. Sokolski, *Gauging US-Indian Strategic Cooperation*, Strategic Studies Institute U. S. Army War Co (January 2007);

of very poor relations with India, not just because of that, many other reasons. But I think that all could have been sidestepped by working with India to arrive at just where they are today.¹⁴⁷

In the light of their reticence and the general cooperative endeavors NASA had nurtured in India -- inclined towards scientific and socio-economic purposes -- it is difficult to say whether NASA offered Scout “blue prints” to the Indians. However, the declassified documents at NARA and NASA and the oral histories clearly tips the balance toward what Gopal Raj asserted in his book *Reach for the Stars* on the history of India’s launch vehicles, i.e. that SLV-3 was built using freely available unclassified reports and that the incremental development of sounding rockets paved the way for developing SLV-3 after a span of fifteen years.

Though SLV-3 resembled Scout in its morphology, the subsystems and the fuel assembly showed marked difference from Scout architecture. Complementing Raj’s work, this section revisits the early history of the origins, aspirations and debates about India’s launch vehicle and looks at the role played by the United States, through NASA, whose fingerprint is evident during the formative years.

My story also brings to light how the Indian scientists and engineers courted different companies and institutions in the US for learning technology. It was only after the United States denied access to technology that the Indian’s sought help from other countries. This is probably due to the extensive networks Sarabhai initiated during the early years of space cooperation and also because many scientists and engineers who worked for the Indian atomic and space program received higher education in the United

¹⁴⁷ Oral History Transcript, Arnold W. Frutkin, Interview by John Krige et.al, Washington D.C., 19th August 2007, NASA History Office, Washington D.C.

States. Relations with Soviet Union on the other hand was limited to defense purchases (weapons and supersonic aircraft). The State Department papers also indicated the preference of scientists/engineers for receiving help from the United States. A message from the U.S. Embassy in New Delhi to the State Department in 1973 remarked that the

U.S.S.R does not appear to be nearly so forthcoming as the Government of India would like.....undoubtedly the Government of India gets most of its foreign weapons assistance from the USSR. Science Attaché, however, has met no Indian technologist very enthusiastic about cooperation with the Russians. Some have indicated that visits to Russia are pleasant socially, but they are restricted in scientific content. Admittedly, Indian discussions with US officials would be somewhat skewed, but Indian scientists appear to get much more from and to prefer to work with the Americans and others in the West. So far there appears to be more talk than substance to science and technology cooperation with Communist countries, but the condition could change rapidly as Indians learn the Russian language.¹⁴⁸

The possibility of aiding India with Scout technology appears on two occasions in my sources: soon after the Chinese nuclear test on October 1964 and again after China's first launch of a satellite on April 1970. What follows is a chronological narrative to highlight the dilemma faced by a plethora of actors in different departments and agencies when it came to space cooperation in the field of launch vehicles. Before getting under way, what is the Scout rocket?

SCOUT

The first time I encountered a Scout rocket was at the Smithsonian National Air and Space Museum in Washington D.C. in 2007 while working on a NASA project

¹⁴⁸Daniel Patrick Moynihan, American Embassy, New Delhi, to Department of State, July 17, 1973, "Space Research and Development in India," box 2919, NARA II.

looking at “NASA’s International Relations.” Later, I had ample opportunity to see the artifact more closely when I was awarded a one year resident Guggenheim Fellowship (2010-11) for completing my dissertation at NASM. The rocket would cross my eye every time when I walked to get some food inside the museum. When I glance at Scout, it always reminds me of SLV-3 and the nascent Indian space establishment in Thumba, a place very familiar to me.

The Solid Controlled Orbital Utility Test (SCOUT) system, was an all solid four stage rocket capable of launching a satellite weighing 385 pounds into a 500 mile low earth orbit. It was one of the most widely used launch vehicles for lofting scientific satellites both for the United States and also for many foreign nations. It’s known for its “simplicity, productivity and reliability.” The designers built the rocket by integrating solid fuel rocket motors derived from ballistic missiles: “the first stage motor was a combination of the Jupiter Senior and the Navy Polaris; the second stage came from the Army Sergeant; and the third and fourth stage motors were designed by Langley engineers who adapted a version of the Navy Vanguard.” It had a simple open loop guidance system – the trajectory was predetermined.¹⁴⁹

Debating the Transfer of Scout Technology to India

As indicated earlier, soon after the Chinese nuclear test in 1964, Bhabha and Sarabhai made several visits to the U.S. requesting advanced boosters that could be used to launch satellites. In February 1965 Robert F. Packard from the Office of International

¹⁴⁹ <http://www.nasa.gov/centers/langley/news/factsheets/Scout.html> (accessed on 28 February 2011). For a more detailed analysis of the development of Scout rocket see, Hunley, J D. *The Development of Propulsion Technology for U.S. Space-Launch Vehicles, 1926-1991* (College Station: Texas A&M University Press, 2007).

Scientific Affairs, in anticipation of Bhabha's visit, sent a memorandum to Frutkin asking for the "cost, timing and dependence upon foreign assistance" for India to extend its space program to satellite activities and the modalities of U.S. cooperation in this arena. This memo, coming soon after the Chinese nuclear test, sought possible routes for India to regain regional influence using space endeavors, rather than taking the nuclear path. Packard's question to Frutkin was narrowed down to four possible ways of launching a satellite made in India, successively involving a greater intimacy of Indian engineers themselves with launcher technology (see the below table)

Table 3: Options for launching a satellite for India

Origin of launcher	Location of Launch	Launch assistance
Foreign	Abroad	Foreign
Foreign	In India	Foreign
Foreign	In India	Indian
Indian	In India	Indian

Frutkin responded in detail to the queries and did not think that India could do much in the short-term. Regarding the time-frame, he pointed out that even if India made fundamental progress in major areas in the development of a booster within five years, U.S., Japanese and French experience suggested that India could not complete a total (emphasis in the original) booster system in this time, nor within seven or eight years, without significant U.S. assistance. Alternately, if the U.S. agreed to cooperate, it would be only "partially an indigenous development" and the whole process would "involve highly visible foreign assistance" implying that it would defeat the purpose of boosting

India's prestige in the subcontinent using space technology. Comparing the Indian case with France and Japan he noted that the Japanese had been working on solid propellant technology for close to ten years with a fairly large industrial base without any concrete results. Similarly, the French had been working for at least six or seven years toward building a satellite launch vehicle without reaching their objective (France launched Diamant just a few months after Frutkin made this comment- see below). Frutkin noted that India might also have difficulty with respect to several systems that go with the launcher -- telemetry, command, guidance, test, and check out systems. He categorically stated that such an extensive program would "preempt all of the known Indian competence in the necessary areas for a period of years roughly related to the period of time used by France and Japan." If the United States were to speed up the "Indian National" booster program, the time required could be reduced substantially. Scout guidance, for example, was not classified and could very likely be made available to India under existing policy (this system is essentially an attitude reference system with limited value in U.S. terms for strategic purposes).¹⁵⁰ Nevertheless, substantial numbers of personnel would be required to work in India, with inevitable publicity and high costs.¹⁵¹

Frutkin made a detailed analysis of the cost factor for India to develop a launch vehicle and also a satellite. He projected the overall cost to India to be \$ 55-65 million -- \$ 45 million for building a launcher and another \$11- 15 million for launch facilities; the time frame was 7-10 years. Since this equipment and instrumentation was "peculiar" to

¹⁵⁰ Scout used an open loop guidance (more information on this guidance package is given below).

¹⁵¹ Memorandum, Frutkin to Robert F. Packard, Officer in Charge, Outer space affairs, Office of International Scientific Affairs, Department of State, Feb 5, 1965, folder Space and Astronautics, box 10 NARA II.

the launch vehicle it had to be purchased from an American manufacturer or constructed in close collaboration with them. He pointed out that Thumba was small and not a conducive location for satellite launching, so he favored a launch site on the East coast.¹⁵² It appears in the memo that Sarabhai had already done a cost analysis of a “partially independent Indian booster development program for a Scout type vehicle at \$ 25 million using French and Japanese technology.”¹⁵³ On the question of satellites he stated that it would cost around “2-4 million and would take the Indians three years with foreign assistance.” If India sought the help of Japan and France “India could probably produce a satellite launch vehicle in 8-10 years.” If U.S. was forthcoming to help, it could be reduced to 7-8 years.¹⁵⁴

Frutkin concluded that the assistance required to bring a “total satellite program” to fruition would undoubtedly go well beyond established criteria for cooperative programs to a degree easily recognized abroad. On the other hand, he suggested that the cost and time could be significantly reduced if the Indians were to use a Scout in America. If, as in the case of the Italian San Marco project, the arrangement were to be a cooperative one between NASA and the Indians, NASA could provide the launch vehicles at a cost of about \$ 3 million to the U.S. This latter alternative assumed that the project would be of sufficient scientific or political value to America to justify direct U.S. involvement and expenditure.¹⁵⁵

¹⁵² A launch base in the east coast was first hinted here. By the late sixties Sarabhai established Sriharikota launch range on the eastern coast close to Madras (now Chennai).

¹⁵³ Memorandum, Frutkin to Robert F. Packard, Officer in charge, Outer space affairs, Office of International Scientific Affairs, Department of State, Feb 5, 1965, folder Space and Astronautics, box 10 NARA II.

¹⁵⁴ Ibid.

¹⁵⁵ Ibid.

By the time of Bhabha's visit, the State Department and NASA officials had already discussed the issue of Scout technology for the Indians. On 21 February, 1965, Bhabha asked Frutkin about the cost and time factors for the development of a small satellite booster system, to which Frutkin responded that the Scout itself had been approved by the Department of State as available in principle under suitable terms and conditions for purchase by other countries in connection with scientific research. "The transfer of this technology however, is quite a different question as you know. And would be a matter for determination by the Department of State under Munitions Control procedures."¹⁵⁶

NASA and Prof. G.B. Pant at the Birla Institute

The earliest request to the U.S. for assistance with rocketry came from G.B. Pant, a scientist based in the Birla Institute of Technology, who expressed a desire for assistance in establishing a Department of Rocketry at the university level in India.¹⁵⁷ The request was refused citing the potential strategic military implications.¹⁵⁸ The United States had no security agreement with India under which assurances were given for the protection of sensitive classified information. "The Indian government made several

¹⁵⁶ Letter, Arnold Frutkin to Homi Bhabha, March 10, 1965, folder SP-Space and Astronautics, RG 59, Bureau of International Scientific and Technological Affairs, box 10, NARA II.

¹⁵⁷ Birla Institute was jointly sponsored by MIT and Ford Foundation, see Stuart W Leslie, and Robert Kargon, "In the Shadow of the Superpowers - Exporting MIT: Science, Technology, and Nation-Building in India and Iran," *Osiris* 21 (2006): 110.

¹⁵⁸ The memo indicated that "because of military connotations of many item of rocket equipment and technology restrictions have been imposed on the export of many classes of items. Applications for export of rocket equipment or technology must be submitted to the U.S. Department of State for approval....with regard to propellant technology, I should advise you that the U.S. government is reluctant to permit the export of knowledge of manufacturing techniques see memorandum from Wreatham E. Gathright, Chief, Outer Space Matters, Office of the Special Assistant to the Secretary for Atomic Energy and Outer Space, to Arnold Frutkin, Director, Office of International Programs, National Aeronautics and Space Administration. Subject: Space Cooperation with India, October 19, 1961, RG 59, General Records of the Department of State, Special Assistant to the Secretary for Energy and Outer Space, Records Relating to Atomic Energy Matters 1944-63, box 250, NARA II.

requests in the past for classified military equipment and in each case these requests were dropped or withdrawn when the U.S. Government indicated that no action could be taken without a security determination in accordance with U.S. national disclosure policy.”¹⁵⁹ However, in 1964, Professor Pant again approached NASA with the “endorsement” of Sarabhai seeking NASA support for the assignment of an American academic expert in solid rocket propulsion theory to spend a year initiating a research program at the Birla Institute. The U.S. Department of State gave a favorable response and NASA arranged with Princeton University to send Maurice Webb to work on the theoretical aspects of rocket propulsion. After the completion of Webb’s “tour-of duty” Pant again asked for two experts in the field of propulsion and aerodynamics. Seeing the pace at Birla moving from theory to praxis with close coordination with Sarabhai’s INCOSPAR proposal for building small rockets, Frutkin sent a cautionary confidential memo on 25 August, 1965 to J. Wallace Joyce, Acting Director, International Scientific and Technology Affairs in the Department of State about the risk of supporting such an academic endeavor and also about NASA’s position on small rockets and launch vehicles. Frutkin also informed Joyce about Sarabhai’s forthcoming visit to the United States in the Fall of 1965 for recruiting fifteen Indian engineers residing in the United States for a solid rocket development program to be carried out in India.

With regards to NASA policy on small rockets, Frutkin stated that, “NASA has so far carefully avoided contributing to rocket development program abroad.” Secondly, Frutkin stated that progress was being made in India through the license agreement with

¹⁵⁹ Memorandum, Wreatham E. Gathright, Chief, Outer Space Matters, Office of the Special Assistant to the Secretary for Atomic Energy and Outer Space, to Arnold Frutkin, Director, Office of International Programs, National Aeronautics and Space Administration. Subject: Space Cooperation with India, Dated: October 19, 1961, RG 59, General Records of the Department of State, Special Assistant to the Secretary for Energy and Outer Space, Records Relating to Atomic Energy Matters 1944-63, box 250, NARA II.

Sud-Aviation for the production of the French Centaure rocket and through consulting assistance from professor Itokawa of Japan. “The development of solid rockets is understood to be underway in other Asian countries, including Pakistan and Indonesia. Assistance to India in this area would become known and would constitute a precedent for assistance to other countries.” Frutkin cautioned that the “US could easily become involved in a series of rivalries with tactical and strategic delivery implications.” He pointed out that Pant was not “candid” enough to tell of the close relations nurtured between INCOSPAR and his Birla Institute of Technology in advancing solid rocket development. Frutkin said that while “NASA desires to accommodate the Department’s interest [it] is concerned that assistance in the Birla program as now understood might compromise NASA’s international space responsibilities, involve NASA in a difficult precedent with regard to other countries, and might contribute to nationalistic competition with military implications.”¹⁶⁰

After this episode during the mid sixties, archival papers do not indicate any further information on the debate about technology transfer in the field of launch vehicles. The issue again emerges soon after the Chinese satellite launch in 1970. In the intervening period official annual records, brought out by the Department of Atomic Energy, indicate that Sarabhai promoted the indigenous production of launch vehicles through the incremental development of sounding rockets. This is evident from his address at the UN conference in Vienna and the institutional developments directed toward the needs of a budding launch vehicle program.¹⁶¹

¹⁶⁰ Confidential memorandum, Arnold Frutkin to J. Wallace Joyce, “Support of Birla Institute, India”, August 25, 1965, RG 59, box 3140, NARA II. (emphasis mine)

¹⁶¹ See the flow chart in chapter 2 (p.86) for various organizational and institutional framework.

At the United Nations Conference on the Exploration and Peaceful Uses of Outer Space in Vienna in 1968 Sarabhai spoke about the importance of an indigenous capability and the complex political implications when a country had to depend on another for launching its satellites. He said “the military overtones of a launcher development program of course complicate the free transmittal of technology involved in these applications.”¹⁶² By 1968 he had already done a cost analysis of building a launch vehicle program and the required ground systems, including a launch pad on the eastern sea coast. He factored in the costs of a scientific pool for supporting a fully-fledged program.¹⁶³

The Chinese launched Long March I (CZ-1) on 24 April, 1970, placing the Dong Fang Hong (the East is Red) DFH-1 satellite in low earth orbit. Though launched a few months after the Japanese launch of the Osumi satellite in February 1970 using the Japanese Lambda rocket, the Chinese launch triggered an outcry in India. The debate in India, soon after launch, centered on whether India should develop a nuclear deterrent against China and the resultant opinion was highly in favor of one. The then Defense Minister Swaran Singh “reaffirmed” before the Indian parliament that he would “review the possibilities for an accelerated space program.”¹⁶⁴ After the Chinese launch Vikram Sarabhai visited Washington and sought U.S. cooperation in building an Indian launching capability and also on guidance and control technology. The memo, after detailing the situation in India, expressed caution that “US denial would generate serious irritation in Indo-US relations, would turn Indians to other suppliers and would inhibit our capacity to

¹⁶² Kamala Chowdhry, *Vikram Sarabhai: Science and Development*, pp. 36-37.

¹⁶³ The Sriharikota Range became operational with the firing of RH-125 sounding rocket on 9 October 1971.

¹⁶⁴ Secret Memorandum, American embassy, India to Secretary of State, April 30, 1970, “Indian Reaction to Chicom Satellite,” RG 59, box 2962, NARA II.

monitor (emphasis mine) Indian space research developments, and our ability to influence developments toward peaceful rather than military applications.”¹⁶⁵

A confidential memo from the American embassy in New Delhi to the Secretary of State dated August 1970 highlights the pros and cons of cooperating with India in the field of launch vehicles. The pro arguments were that a close cooperation will help to “monitor the Indian program” and since India could buy technology and hardware elsewhere it would be “preferable for India to be associated with US in this regard.” The memo also noted the “commercial opportunity for US exports” if the United States assisted India in the supply of “unclassified technology and hardware.”¹⁶⁶ However, the negative arguments far outweighed the pro arguments for any meaningful cooperation. The United States government was aware of the rhetoric of the Indian political elite that “only a nuclear equipped India can win a rightful place in counsels of major powers” and any assistance could “stimulate advanced rocket development” and enhance the early development of “Indian nuclear weapons system.” The U.S., as one main architect of the Nuclear Non Proliferation Treaty (NPT) and an opponent of Indian nuclear weapons development, would not even indirectly wish to facilitate such an Indian decision. Secondly, the memo stated that “India’s overall economic development could be imprudently retarded by major expenditures in atomic and rocket fields.” The embassy officials were also leery of the *Profile for the Decade* report brought out by the Department of Atomic Energy and saw the space plans as a needless diversion of India’s pressing needs into a strategic build up – “Sarabhai’s ambitious program far too

¹⁶⁵ Secret Memorandum, American Embassy to Secretary of State, April 30, 1970, “US Assistance to Indian Satellite Program,” RG 59, box 2962, NARA II.

¹⁶⁶ Confidential memorandum from American embassy New Delhi to Secretary of State Washington D.C. 23rd August 1970, RG 59, General Records of the Department of State, Subject Numeric files, 1970-73, Folder Science, box 2962, NARA II.

expensive given India's other pressing needs for the GOI to accept it in its entirety."¹⁶⁷ The officials also feared that helping India would also send the wrong signals to China and Pakistan concerning American policy on international military applications of science and technology. They saw that if the U.S. provided technology to India and not to other interested countries it would have "corrosive effects" on U.S relations elsewhere. They feared that a "premature US commitment could inadvertently nudge Government of India's program into direction Indians might later find fruitless, with possible consequent recriminations against U.S." In light of these facts, the embassy recommended a flexible long range policy of selective cooperation and restraint whereby the United States could provide India unclassified technology and other types of assistance directed toward India's peaceful economic and social development.¹⁶⁸

Anthony C.E. Quainton, Senior Political Officer for India in the State Department, discussed the issue of providing launch vehicle assistance with U. Alexis Johnson the Under Secretary of State who had extensive experience in sharing of rocket technology with Japan. He favored a joint collaboration with the Indians up through the Scout level in unclassified technology on propulsion systems without financial support and with suitable assurances about peaceful use. He was aware of the meeting between Arnold Frutkin and Sarabhai in Palo Alto, California. With technology out of bounds,

¹⁶⁷ U.S. Embassy (New Delhi) to State Department, airgram, no. A-329, June 16, 1970, p. 10. Nuclear Non – Proliferation Policy, FOIA files, India, National Security Archive, Washington D.C. Cited in George Perkovich, *India's Nuclear Bomb: The Impact of Global Proliferation*, p. 155.

¹⁶⁸ Confidential memorandum, American Embassy, New Delhi to Secretary of State Washington D.C., 23rd August 1970, RG 59, General Records of the Department of State, Subject Numeric files, 1970-73, folder Science, box 2962, NARA II.

Sarabhai appears to have asked Frutkin if he could at least establish academic links and that if a few of India's scientists and engineers could be hosted at select installations.¹⁶⁹

By November 1970 we see a determination in India to launch its own satellite using indigenous technology. Frutkin's assistant, Dick Barnes wrote that the Indians were interested in two different programs using their own launch vehicle for their RS-1 satellite and the Scout for certain special scientific experiments using a RS-2 satellite. NASA estimated they could do this by 1975 or 1976. The RS-2 could be launched within about three years of the signature of a U.S.-Indian agreement. Sarabhai may also have been interested in a third alternative under which America would launch a Scout from an Indian range. This had certain attractions because of the geographical location of the Indian range that was preferable to any range in this U.S. though it was not quite as good as the San Marco platform off the coast of Kenya. When the idea of transferring a Scout and launching it from an Indian range was floated NASA looked at the alternative "somewhat wistfully" because of the possibility that it could in effect deter the Indians from developing their own launch capability.¹⁷⁰

On 22 December, 1970, Joseph T. Kendrick sent a proposal to Robert A. Clark of Munitions Control (MC) asking him to agree to assist India on similar terms as agreed between America and Japan. Clark's reply indicated that he had no policy objection to the substance of the proposal, however, he expressed reservations about sending the proposal to U. Alexis Johnson for approval as it had not been discussed with NASA and

¹⁶⁹ Meeting between Frutkin and Sarabhai is mentioned in the memorandum between Anthony C.E. Quainton, Senior Political Officer for India (US State Department) to Harmon E. Kirby, American Embassy, New Delhi, September 24, 1970.

¹⁷⁰ Memorandum, Anthony C.E. Quainton, to David T. Schneider, November 5, 1970, "Space Cooperation with the Indians," folder SP 13 - Rockets & Boosters, RG 59, Records Relating to India 1966-75, box 12, NARA II.

the US Department of Defense (DOD). Clark requested Kendrick to forward the proposal to them first. He explained the nature of the arrangement for Japan. A Technical Advisor Group (TAG) was set up consisting of representatives from NASA, DOD and State Department to consider each American industry application for the transfer of hardware technology to Japan. He drew attention to the vagueness of the offer to cooperate in the development of a limited space program “up to and including the general level of Scout Rocket Technology.” In the U.S. – Japan program the term ‘Thor Delta Technology’ had not been specified by either the U.S. or Japan to facilitate case-by-case export application processing. In coming to an agreement with India, it would be helpful if the administration’s agencies, and possibly American industry, were first to have a clear understanding of what was meant by “Scout technology” in each of the areas in which American assistance would be provided. The Office of Munitions Control would compile a list of hardware and technology that had been licensed for export to Japan to help the DOD and NASA. Clark said that he knew “from personal experience that Indian officials are aggressive and persistent individuals who might be more likely to cry foul whenever they believe correctly or incorrectly that their understandings differ from someone else’s understandings.” Thus, wrote Clark, “the USG position on what scout technology means should be prepared in advance and not left to chance as has been done with the Japanese and Thor-delta technology.”¹⁷¹

Three years later we find that, though critical elements of launch vehicle technology were denied, the declassified State Department papers indicate the approval of some “hardware” related to sounding rockets and satellites, which are “unsophisticated

¹⁷¹ Robert A. Clark, jr to Joseph T. Kendrick, 29 December 1970, “U.S. – India Space Cooperation,” RG 59, box 2962, NARA II.

in character.” However, the Indian space program was closely watched for potential ballistic missile activities. And the memo indicates that “So far, the Indian program appears peaceful in character - as the Indians claim - but it is developing the technological capability for a missile system should the Government of India opt for this course.” The memo also stated about how they perceived the Indian space program,

“originally the Indians hoped to launch a satellite in 1974. The time table has slipped badly and it is unlikely, they can attain their goal until much later. One factor has been the weakened leadership in the space program since the death of Sarabhai. Since then atomic energy and space have been separated, into two organizations. The new directors lack the dynamism and influence that Dr. Sarabhai possessed. Another factor has been India’s economic difficulties which have made it harder to get financial resources for the programs such as space research and development. In a political/military sense, we have been trying to keep a watch on the Indian program to determine whether the Indian’s were trying to develop a ballistic missile capability. This could, of course, be used as a delivery system for a nuclear weapons system.”¹⁷²

The last available discussion on the subject was in a confidential memo from Sipes to Scisco on 27 June, 1973, requesting the formulation of a departmental position on whether it would be in the overall interest of the U.S. to assist India in the development of its space program. The question was prompted because the Office of Munitions Control had received a number of requests from U.S. industries for Department of State approval to export space hardware and technology for India’s space program. The hardware included components like gyros and accelerometers that were

¹⁷² Confidential memorandum David T. Schneider to Ambassador Meyer, April 5, 1973, “Your appointment with Werner Von Braun,” RG 59, General Records of the Department of State, Records Relating to India 1966-75, folder Science, box 25, NARA II.

essential for the guidance and control of launch vehicles and missiles.¹⁷³ It seemed that the Indians sought these components for building an indigenous launch vehicle. Since the approval of any of these components and system would establish a precedent, the memo sought answers to “whether this would be in the U.S. interest to help India develop its space program - satellite and launcher development -- and would such assistance be in furtherance of world peace and the security and foreign policy of the United States. If the answer to the above question is yes, then how far, or up to what level should our assistance go?” As a comparison, Sipes brought the Japanese case of Thor-Delta technology transfer and explained how the Japanese had undertaken to use the launch vehicle and satellites developed with U.S. assistance on condition that they would be used for peaceful purposes only. Japan also had to agree not to transfer such articles or related technology to third countries without U.S. government consent and to use them consistent with Intelsat arrangements. Because the Indian government in April announced that it was developing missiles for its services, Sipes said that it was not “prudent to permit the release of space hardware and technology” especially gyros and accelerometers which were critical for inertial navigation systems.¹⁷⁴ Within a year India conducted its first nuclear test calling it “peaceful nuclear explosion (PNE).” An indigenous SLV-3 was attaining maturity.

¹⁷³ Rockwell International (formerly North American Rockwell) had asked for authorization for its UK licensee, Rolls Royce, to transfer rocket engine technology and experience; Honeywell inc. wanted to export certain quantities of two different types of gyros and Kearfott, Division of Singer co. applied for two licenses, one that would permit its UK licensee, Ferranti, to sell certain gyros and the other that would allow the export of US made gyros and accelerometers.

¹⁷⁴ Confidential memorandum, John W. Sipes to Joseph J. Sisco, Jun 27, 1973, “US Posture Towards Indian Space Program,” RG 59, box 2962, NARA II.

“SLV-3 was 100 percent indigenous”

Abdul Kalam ¹⁷⁵

India’s first satellite launch vehicle (SLV-3) was an all-solid, four-stage rocket that placed the Rohini satellite in near circular orbit. The four stages were planned, designed and built at Vikram Sarabhai Space Center (VSSC), at Veli Hills, adjacent to TERLS in the state of Kerala. After completion, the stages were moved, assembled, and launched from Sriharikota (SHAR), located on the eastern sea coast in the state of Andhra Pradesh – about 500 odd miles Northeast of Thumba. The feat was accomplished by hundreds of scientists and engineers, with the help of “13 nation institutes, 40 major industries and 1000 medium/small scale industries.” ¹⁷⁶ There were three launches in total: SLV-E1 (1979), SLV-E2 (1980) and SLV-D1(1981). The first successful launch on 18 July 1980 demonstrated the satellite launch capability and it also proved the overall functioning of all the major subsystems of the vehicle. ¹⁷⁷ The following paragraphs chronologically narrate the evolution of SLV-3 in India.

In a recent article space historian Asif Siddiqi has offered new avenues for space historians to move beyond nation-centered approaches – “deemphasizing ownership and national borders.” Doing so, he believes, would unveil a richer tapestry of transnational “knowledge” flows in the evolution of space technology. Also, rather than being transfixed on the nation-state, “one can shift our gaze from nations to communities, from

¹⁷⁵ Ashok Maharaj, interview with Abdul Kalam, January 18, 2009.

¹⁷⁶ Vikram Sarabhai Space Center and Astronautical Society of India, *Development of SLV-3: Retrospective* (Thiruvananthapuram: SB Press, 2005), p. 9.

¹⁷⁷ SLV-3-E1 (E denoting experimental) was launched on August 10, 1979 was a failure. After the second successful launch of SLV-E2 on 18 July 1980 the third launch vehicle SLV-D1 (D denoting developmental) was launched on 31 May 1981, was declared partially successful when the satellite did not reach the desired orbit.

‘identification’ to identities, and from moments to processes.” Taking the cue from Siddiqi’s approach I have narrated the efforts taken by a community of scientists, engineers/technologists, mostly young and fresh graduates, to actualize Sarabhai’s long held vision of launching an ‘indigenous’ satellite on an ‘indigenously’ made launch vehicle.¹⁷⁸

To recap, Vikram Sarabhai’s long held vision of using space for socio-economic development included the development of launch vehicles for domestic Indian needs. To achieve that goal, early efforts at indigenous production of sounding rockets using French Centaure sounding rockets was taken by a team of engineers at Thumba under Sarabhai’s leadership. The objective was to start from scratch and gradually scale up the rocket to achieve satellite launching capability. However, the geopolitical situation in South Asia -- only exacerbated by the Chinese nuclear test of 1964, and the evolution of Intelsat – an American led and maintained communications satellite system which portended a complete dependence on the American system for all future communication needs of India, -- triggered a more realistic goal of getting technology for a small launcher from the United States initially and building domestic institutions and infrastructure to develop higher capability rockets progressively.

Following behind the scenes negotiations at Foggy Bottom, NASA headquarters, and extended meetings at international conferences, Sarabhai made public pronouncements of a launch vehicle soon after the UN Conference in Vienna in 1968. Concrete efforts followed after the publication of a ten year plan called *Profile for the*

¹⁷⁸ Asif A. Siddiqi, “Competing Technologies, National(ist) Narratives, and Universal Claims: Toward a Global History of Space Exploration,” *Technology and Culture* 51, no. 2 (April 2010):425-443.

Decade for nuclear and space research (see chapter 2).¹⁷⁹ In the profile, Sarabhai explicitly spoke of the indigenous building of a satellite launch capability for “many applications of outer space in the fields of communications, meteorology and remote sensing.” He also gave the performance specifications of an all solid four stage satellite launch vehicle weighing 20 tons, and capable of launching a satellite weighing 30 kgs in a 400km low earth orbit. The profile stated that sensitive instruments, electronics and instrumentation, would be flight tested using sounding rockets. Sarabhai also talked about a follow on program, an indigenous launch vehicle to place a 1200 kg satellite in geo synchronous orbit to “fully exploit the vast potential arising from the practical applications of space science and technology”¹⁸⁰

Though the public presentation of SLV-3 was made through the *Profile*, institutional developments and planning started much earlier. To help with the new field of advanced rocketry and associated subsystems, Sarabhai began recruiting fresh graduates, mainly from United States, for rocket research and development at Thumba during the mid nineteen sixties. Among his recruits was a young aeronautical engineer Y. J. Rao. The early history of SLV-3 owes a lot to this person. During my field trip to Trivandrum, I had the privilege of seeing many of the seminal project reports prepared by him on the feasibility and design aspects of the launch vehicle for India. Though an important figure, not much information is available on him. I enquired about him from the VSSC staff and also Y.J. Rao’s contemporaries but no one knew his whereabouts. By

¹⁷⁹ Ashok Maharaj, interview with E.V. Chitnis, February 2009. Chitnis stated that Sarabhai knew very well that a five year plan model adopted by the Indian government would not work for the space and nuclear sector because of the long gestation phase in achieving targets hence he opted for a decade plan.

¹⁸⁰ Atomic Energy Commission, *Atomic Energy and Space Research: Profile for the Decade* (Bombay:1970), p. 28.

sheer luck I was able to meet him recently. What follows is a brief description of Y.J. Rao – his early life and his contributions the development of space technology in India.

*Yellamanchili Janardana Rao*¹⁸¹

Y.J. Rao was born on 12 August 1930 in the State of Andhra Pradesh, a Telegu speaking state in South India. After completing his bachelor's in Math from Andhra University in 1952, he went on to get a post-graduate diploma in Aeronautical Engineering from Madras Institute of Technology (MIT), in 1956. Further, he pursued his Masters and PhD in Aeronautical Engineering from University of Minnesota, Minneapolis, USA in April 1963. I asked him why Minnesota? "it's because of existing networks already established in India, few of my seniors went to Minnesota so I too opted for it, but I was clueless about the extreme cold weather. After basking in the hot and humid tropical weather in South India, it was both a culture and weather shock for me in Minneapolis," he said.¹⁸²

During his graduate training, he worked as Research Engineer in the University Aeronautical laboratories, using supersonic and hypersonic wind tunnels. This involved testing of rocket and re-entry models in wind tunnels. From September 1962-August 1963 he worked as a research associate at University of Alabama Research Institute, in Huntsville, Alabama. Here he worked on re-entry aerodynamics and also participated in the design and development of Aeronautical facilities. After his PhD he worked briefly on missile control systems and fluids at Systems and Research Laboratory at Honeywell

¹⁸¹ I had the privilege of meeting Dr. Rao, at his residence in suburban Maryland, USA. Tall and dark in complexion, typical of many south Indians, he greeted me with a husky voice, and asked how he could be of help to me. I expressed my sheer joy at meeting him and inquired about his life at Thumba and contributions toward rocketry and the construction of SHAR until he moved to the United States in 1976.

¹⁸² Ashok Maharaj, interview with Y.J. Rao, April 13, 2011.

in Minneapolis. His last training in the US was at Ames Research Center, Mofett Field, California, where he worked on re-entry aerodynamics. During his stint at California he also took an advanced postgraduate course in specialized advance field of high temperature gas dynamics at Stanford University.

While pursuing his training he came across a posting in *India News*, a widely circulated newsletter periodically brought out by the Indian Embassy in Washington D.C., about job openings in India in the field of space science and technology. Sarabhai personally interviewed him in Washington D.C. on September 3, 1966, and appointed him on October 15, 1966, to head the Aerodynamics and Structural Engineer in the Rocket Research and Development Group (precursor to SSTC) at TERLS.¹⁸³ Upon joining, he became fully involved in the fabrication of sounding rockets – license production and indigenous ones. He prepared the Design Study Program and Flight Performance of Centaure sounding rocket and also surveyed all sounding rocket programs of various COSPAR member-countries. He successfully led the indigenous production of a series of indigenous Rohini sounding rockets.¹⁸⁴

Seeing his educational background and training in rocketry, and his efforts toward indigenous production of sounding rockets, Sarabhai contacted him in the Spring of 1968, for the initial feasibility studies on developing a satellite launch vehicle. With the assistance of the electronics engineer Pramod Kale, a vehicle configuration based on four stage solid propellant rocket, which would be ideal for Indian conditions, was chosen.¹⁸⁵

¹⁸³ Memorandum, Vikram A. Sarabhai to Janardanarao Yalamanchili, November 18, 1966, Y.J. Rao papers, possession with the author.

¹⁸⁴ Memorandum, “Tasks of Y. Janardana Rao” 17 February 1967, Y.J. Rao papers.

¹⁸⁵ Gopal Raj, *Reach for the Stars*, p. 50. In addition to this, its important to add that Pramod Kale is well known among NASA officials. He spent three years at Goddard Space Flight Center.

Sarabhai elevated him to be the Project Manager for SLV design. During this time he wrote a lot of reports on the SLV along with ISRO engineers.¹⁸⁶

By late 1970 the design phase was completed and of six designs Sarabhai chose the third, hence the name SLV-3.¹⁸⁷ Unlike indigenous meteorological sounding rockets named after mythical celestial beauties -- *Rohini* and *Menaka*, borrowed from Hindu scriptures--the first launch vehicle was blandly named SLV. The next one year was spent designing the SLV – stage configuration, and by October 1971 the design was completed. It was a vehicle measuring 22 meters in length and 17 tons in weight capable of placing a 30 kg satellite into near-earth orbit. The configuration was very similar to the first generation Scout rocket.

From 19 April to 5 June, 1970, even before the launch range on the eastern coast was formalized, he was sent to West Germany, France, England, French Guyana, United

¹⁸⁶ Y. Janardana Rao, et al., *Performance Study of Satellite Launch Vehicles*” presented at the Technical Session of 21st Annual General Meeting of the Aeronautical Society of India at the Indian Institute of Technology, Madras on April 5, 1969; K. Narayana and Y. Janardana Rao, *Two Dimensional Trajectory Simulation of Multistage Rockets*, Space Science Technology Center (SSTC), 1969; Y.J. Rao, et.al., *A General Purpose Program Package for Satellite Launch Vehicle Design and Performance Simulation*, SSTC, 1969; Y.J. Rao, *Performance Study of Satellite Launch Vehicles*, SSTC, 1969; Y.J. Rao, *Performance and Optimization Study of Satellite Launch Vehicles* (2 volumes) November and December 1969; Y.J. Rao, *The Performance Study of Satellite launch Vehicle Using Three Dimensional Six Degrees of Freedom Trajectory Simulation*, 1970; Y.J. Rao, *Design and Performance Optimization Study and Application of Satellite Launch Vehicles* March 1970; Y.J. Rao, *Major Subsystems Identification (Satellite Launch Vehicle Development Project)* June 1970; Y.J. Rao, *Detailed Subsystem Identification (SLV Development Project)*, August 1970; Y.J. Rao, *Design Report of SLV 3 Systems Integration*, October 1971; *Design Report of SLV-3 Flight Dynamics*, October 1971; Y.J. Rao, *Design Report of SLV-3 Inter-Stages Structural Design*, October 1971; Y.J. Rao, *Project Management Plan of SLV Developmental Phase*, October 1971; Y.J. Rao, *Subcontracting Details of Satellite Launch Vehicle Project*, February, SSTC, 1972; Y.J. Rao, *Satellite Launch Vehicle, A Brief Review Progress and Management*, SSTC, February 1972; Y.J. Rao, *Feasibility Study of Multistage Ballistic Missiles Using Satellite Launch Vehicle (SLV-3) Booster and Rohini Rockets*, July 1972; Y.J. Rao, *Project Satellite Launch Vehicle*, Report to Space Commission, July 1972.

¹⁸⁷ The number of designs is not clear. “SLV-3 design started in 1970 based on feasibility study to configure a four stage launch vehicle which could inject a 30 kg satellite into near earth orbit. Sarabhai who was chairman of ISRO formed 11 design projects. On completion of the design projects when the development work was to be initiated the untimely death of Sarabhai came, A. Sivathanu Pillai, “*SLV-3 Reminiscence*,” *Development of SLV-3: Retrospective*, p. 46,

States -- Cape Kennedy, Wallops Station, Houston, Huntsville, Hawaii; Australia, Japan, for observing satellite launching stations and to have “technical discussions” with engineers and scientists at various space centers regarding the Indian launch vehicle program and “connected matters.” Sarabhai said that the touring of the facilities was of “very urgent nature for the planning and progress of the scientific satellite launching program of ISRO.”¹⁸⁸

On December 2, 1971 Sarabhai made Rao the Project Manager of SLV-3 and assigned him the following tasks: to coordinate the development of various sub-systems, development of inter-stage structures, freeze specifications and quality control protocols in consultation with sub-system project managers, provide support for transport and handling, integration of vehicle, conduct flight dynamics and flight testing of SLV-3 as a whole, and finally to maintain a centralized documentation center to serve as an information node for all projects related to SLV-3. He would also consult with other project managers for the choice of subsystems for SLV-3, and the evaluation of all test results during the development phase.¹⁸⁹

After Satish Dhawan took over as Chairman of ISRO, Rao was assigned as the Project Engineer Sriharikota Rocket Launch Complex and Rocket Sled Facility (September 1972 to 1976).¹⁹⁰ “He was deputed to visit French Guiana, France and US from 20th November 1972, to 8th December 1972, to attend the International Conference –

¹⁸⁸ Memorandum, Vikram Sarabhai, April 4 1970 (Recipient not disclosed), Y.J. Rao papers.

¹⁸⁹ Memorandum from Vikram Sarabhai, “Responsibilities and Powers of Project Manger - SLV-3,” December 2, 1971, Y.J. Rao papers.

¹⁹⁰ Memorandum, Satish Dhawan, September 25, 1972, Y.J. Rao papers.

Launching Bases at Kourou and to visit various rocket sled facilities in France and US and also NASA satellite launching stations.¹⁹¹

By the time Rao left for the US at the end of 1976, he had close to seventy publications to his name and he also did a feasibility study of multistage Ballistic Missiles using SLV-3 booster and Rohini Rockets in 1972. Coming soon after the restructuring of the Indian space program, and the Indo-Pakistan war of 1971, this is documentary evidence for the dual purpose of SLV-3. His papers also indicate that he did “the calculation of Aerodynamic performance characteristics of advanced missiles for the application of defense and orbiting satellites.”¹⁹²

Though a Scout license production agreement never made its way into India, the idea of using a Scout design for India’s first SLV persisted ever since Bhabha and Sarabhai contemplated developing a launch vehicle for India. Being all solid propellant, a technology easier than complex liquids, this seemed to be a possible route that Indians could attempt and succeed. The reason for the adoption of the Scout design rather than the Japanese Lambda or the French Diamant could be because India’s began to think about this possibility before the French or the Japanese had successfully launched a satellite with a domestic launcher. Several years of negotiation, and the familiarity Indian scientists and engineers gained with Scout during their tenure at Wallops Island and other NASA facilities, played a key role when India opted for a launch vehicle. Also, unclassified project reports from NASA were readily available, and the familiarity that scientists had with project reports could have been a valuable plus. Gopal Raj also claims

¹⁹¹ Memorandum, S.R. Thakore, Assistant Director (Admn), ISRO to Vikram Sarabhai, Chairman ISRO, September 22, 1972, Y.J. Rao papers.

¹⁹² Memorandum, “Tasks of Y. Janardana Rao” 17 February 1967, Y.J. Rao papers.

that the Scout model was chosen because “Indians did not then have sufficient experience for *ab initio* design of a launch vehicle.”¹⁹³

Also, we could interpret the request for Scout from another angle. In the year 1962 India was defeated by China in a border war in which India lost some territory in the northern region. This coupled with a the Chinese nuclear test in 1964 and Indo-Pakistan war of 1965 could have triggered Bhabha to acquire the all solid Scout with the intention of converting into a ballistic missile if need arose,-- after all Scout itself was an assembly of ballistic missile stages (see the description of SCOUT at the beginning of this chapter). However, when Scout technology was “out of bounds” Sarabhai could have pursued liquid technology from the US, similar to the Japanese case of requesting Delta technology. In thousands of pages from the NARA archives or from the Indian “archives”/reports, I did not come across any information about Sarabhai seeking liquid technology from the US.¹⁹⁴

Though the negotiations on the sharing of Scout technology and critical components did not lead to any tangible results, published articles and government reports indicate the importation of several minor subsystems and components from the United States and Europe that were crucial for the development of SLV-3. With these subsystems the engineers and scientists at ISRO incrementally scaled up their sounding rockets to higher configurations (see appendix I). As indicated earlier, an agreement was signed with Sud Aviation of France to license produce an advanced sounding rocket

¹⁹³ Gopal Raj, *Reach for the Stars*, p. 57.

¹⁹⁴ The Japanese N-1 used Thor-Delta rocket technology provided by McDonnell Douglas under license with the agreement of the Office of Munitions Control (OMC). It was manufactured in Japan within a short span of two years. The technology transfer was made mainly for political and strategic reasons.

called Centaure.¹⁹⁵ Working on Centaure helped in building indigenous Rohini sounding rockets, which were advanced further to carry heavier payloads.¹⁹⁶ Many of the SLV-3 subsystems including the heat shield and guidance were tested using an RH-560 prior to incorporating it in the SLV-3 vehicle.¹⁹⁷ “During the development of SLV-3, various changes were incorporated and the version eventually launched was entirely different from the originally conceived one” said M.K. Abdul Majeed, who was the Project Engineer, Rocket Systems and Configuration Control for SLV-3.¹⁹⁸

After the planning of SLV-3 was completed the recruitment of scientists, engineers/technologists started full swing. Thumba was teeming with scientists and engineers during the early seventies. The spectacle of the Apollo moon landings by the United States in 1969 enthused graduates to join the space establishment to attempt a launch vehicle for India. Developing solid rocket motors for SLV-3 offered a training ground for many engineers and scientists to learn about the essentials of rocketry and chemistry behind rocket propellants. In the process, they also were exposed to the world of global politics and how science and technology was used as a tool of foreign policy, economics of foreign exchange (forex), etc.

¹⁹⁵ For a study on Centaure see M.K. Mukherjee, “Study Report on The Possibilities of Reducing the Foreign Exchange Components of Indian-Made Centaure Rockets,” Space Science and Technology Center, Trivandrum, (undated), VSSC Library and Records Division.

¹⁹⁶ The first sounding rocket RH-75 fueled by a Cordite mixture – (a mixture of nitroglycerine and nitrocellulose) was launched on 20 November 1967, following which a series of indigenously developed sounding rockets were developed RH – 100, RH-125, RH-125s, Menaka I and II, RH 300, RH 300 MK-II, RH 560 (RH denotes Rohini) all using solid fuels.

¹⁹⁷ “As a young engineer I was given the responsibility to organize the development of 3 axis controlled and guided two stage rocket vehicle using RH 560 and Centaur motors to demonstrate C&G technology. Every day we used to have meeting with all the concerned to progress the task. We learned lot of things in the process for the first time to integrate and launch the complex vehicle. The experience and thrill made us fully committed to the program and we never looked backward or laterally. The successful launch of RH-560 gave tremendous confidence to the project team later to go with full scale launch of SLV 3.” E. Janardhana, Dy. Director, LVDE/Project Director, RLV-TD, p.24.

¹⁹⁸ M.K. Abdul Majeed, “Reflections on SLV-3 Projects,” *Development of SLV-3: Retrospective*, p. 51.

During the sixties, as described in the second chapter, the space program in the fishing town of Thumba was science driven. Being an international range sponsored by the UN, domestic and foreign PhD scientists dominated the landscape talking about Langmuir probes, Van Allen belts, equatorial electro jets and discussing esoteric calculations on tropical aeronomy in national and international seminars and workshops. From the Indian side it was spearheaded mostly by Western trained scientists – Vikram Sarabhai, Homi Bhabha, Raman Pisharoty, Praful D. Bhavsar, and others. After Sarabhai died in 1971, and with the restructuring of the space program, and a more ‘vigorous’ government under Indira Gandhi (she was the Prime Minister from 1966-1977; 1980-1984), a new breed of “technologists” emerged on the scene to lead the space program in the 1970s: Brahm Prakash, Satish Dhawan, Muthunayagam, Y.J. Rao, Kurup and A.P.J. Abdul Kalam. All but Kalam received doctoral training abroad, and years later Kalam proudly stated that “I am completely indigenous,” -- meaning he received his engineering training in India.¹⁹⁹

With this new influx of “technologists” the campus was teeming with fresh graduates talking about properties of steel, composite propellants, inertial guidance, gas dynamics and discussed mundane mechanical calculations for satellite injection and specific impulse of solid rocket fuels. Young, fresh *Malayalee* (State of Kerala), *Tamil* (Tamil Nadu), and *Telegu* (Andhra Pradesh) speaking, mostly higher *caste*, engineering graduates received training from a handful of western trained technologists.²⁰⁰ In contrast to this, when the SITE was being planned in Ahmedabad, a town near Bombay (now

¹⁹⁹ John F. Burns, “Self-Made Bomb Maker,” *New York Times*, May 20, 1998, p. A6; cited in George Perkovich, *India’s Nuclear Bomb*, p. 424.

²⁰⁰ Indian states are linguistically divided. Most of the recruits during “SLV-Phase” hailed from Southern India.

Mumbai) in north of India, it was represented mostly by engineers and scientists residing in the North Indian region: Pramod Kale, E.V. Chitnis, Yash Pal, Binod Agrawal, and the recruits were mostly from the surrounding regions – Bombay, Pune, and others. In a recent book Anderson talks about the cosmopolitan nature of the leadership in main scientific and technological institutions:

Overall the leadership was cosmopolitan: a Mumbai-based Parsi engineer was at Atomic Energy in Mumbai (Sethna), a Mumbai – based Kannada physicist was at Bhabha Atomic Research Center -- BARC (Ramana), a Bangalore-based Malayali-Rajasthani physicist was adviser at Defense in Delhi (Nagchaudhuri). Each of them would insist that their provenance, their home districts, and linguistic origins were irrelevant and that they were chosen for these roles on merit alone²⁰¹

However, the cosmopolitanism was only at the leadership level. Underneath this cosmopolitan veneer was a workforce that was peculiarly regional.

The development of subsystems and facility generation commenced in January, 1973.²⁰² A full scale model was first built to get hands on experience on the size and challenging task of assembling, building and integrating various subsystems and making the model into a reality. When Satish Dhawan took over as the Chairman, he made Abdul Kalam as the Project Director and asked Y.J. Rao to establish SHAR.

Avul Pakir Jalaludin Abdul Kalam

Kalam was born and brought up in a coastal town in the Southern State of Tamil Nadu called *Rameshwaram*, a Hindu pilgrimage center 500 km south of Chennai and 200 kms from Thumba (where TERLS is located). A Tamil, Muslim²⁰³, vegetarian, and a life

²⁰¹ Robert S. Anderson, *Nucleus and Nation: Scientists, International Networks, and Power in India* (Chicago: The University of Chicago Press, 2010), p. 448.

²⁰² Vikram Sarabhai Space Center, *SLV Project Bulletin* 1, nos.1 & 2 (1973).

²⁰³ It's rare to find, a Muslim scientists and engineer in such senior positions those days (and even now).

long bachelor he became a key player in India's space and missile program after the death of Sarabhai. After his retirement from government service (ISRO and DRDO) he held many advisory positions. The "missile man" was roped in again for a major project that would fulfill Homi Bhabha's long held vision – a nuclear deterrent. He along with other nuclear scientists and engineers secretly planned and executed the Pokhran II nuclear explosions in May 1998. Owing to Indian domestic politics, he was pushed to become the 11th president of India. Though he achieved an iconic status in India, his profile, unlike Sarabhai, is not that of an international one. Only in April 2009, he became the first Asian to receive the Hoover Medal, given annually since 1930 by the American Society of Mechanical Engineers (ASME). What follows is a brief prolife of his early career.

After his schooling at Schwartz in Ramanathapuram he joined St. Josephs College, a Jesuit institution in the town of Tiruchirapalli for his Bachelors degree in Physics. He developed a fascination for engineering while pursuing his Physics and went on to pursue another bachelor training in Engineering at Madras Institute of Technology (MIT), in Madras (now Chennai). At MIT he was mentored by Prof. Sponder, Prof. KAV Pandalai and Prof. Narasingha Rao. An Austrian immigrant, Sponder taught him "technical aerodynamics"; Pandalai taught him "Aero-structure design and analysis" and finally Rao "theoretical aerodynamics." After his studies at MIT he joined Hindustan Aeronautics Limited (HAL) in Bangalore and received experience in aircraft engine overhauling. His long cherished dream of becoming an air force pilot did not materialize and he later joined Directorate of Technical Development and Production (DTD & P) Air as a Senior Scientific Assistant. It was here, while designing a prototype hovercraft, he

had chance encounter with MGK Menon, who was heading the Tata Institute of Fundamental Research (TIFR) at that time. He was invited to Bombay (now Mumbai) for an interview to join INCOSPAR. Vikram Sarabhai (PRL/INCOSPAR); MGK Menon (TIFR), Shroff, Deputy Secretary of Atomic Energy Commission, interviewed him and he was brought into INCOSPAR. Soon after joining INCOSPAR he was sent along with others to NASA to get hands on experience in sounding rocket integration and safety. Kalam's training in the early 1960s spanned three NASA facilities: Langley Research Centre (LRC) in Hampton, Virginia; Goddard Space Flight Centre (GSFC) in Greenbelt, Maryland; and Wallops Flight Facility at Wallops Island in East Coast, Virginia. In his autobiography, *Wings of Fire*, Kalam recalls seeing a painting, prominently displayed in the Wallops reception room, depicting Tipu Sultan's army fighting the British.²⁰⁴ "The painting depicted a fact forgotten in Tipu's own country but commemorated here on the other side of the planet. I was happy to see an Indian glorified by NASA as a hero of warfare rocketry."²⁰⁵ Kalam could never have imagined at that time that he would later become the next "Tipu" of India to build guided missiles. His NASA training made possible the first sounding rocket launch on 21 November 1963 from the Thumba Equatorial Rocket Launch Station (TERLS) in Southern India. Soon after the launch, Kalam noted, "Many individuals with myopic vision questioned the relevance of space activities in a newly independent nation which was finding it difficult to feed its

²⁰⁴ For more on Tipu Sultan rockets see Denys Forrest, *Tiger of Mysore: The Life and Death of Tipu Sultan* (Edinburg, 1970), p 140. It was the rocket used by Tipu Sultan at the siege of Seringapatnam in 1799 which attracted the attention of the British gunnery expert Colonel Sir William Congreve, who took it as a model and improved upon it to bombard Boulogne in 1806 and Copenhagen in 1807. See J.F.C. Fuller, *The Conduct of War, (1789-1961) A study of the Impact of the French, Industrial and Russian Revolutions on War and its Conduct* (London: 1972).

²⁰⁵ Tipu Sultan was killed in 1799 in the Battle of Burukhanahally, a battle in which the British captured more than 700 Indian rockets and 900 rocket subsystems. These rockets were taken to England by William Congreve and were subjected by the British to what we today call reverse engineering. See A.P.J. Abdul Kalam and Arun Tiwari, *Wings of Fire: An Autobiography* (Hyderabad: Universities Press, 1999), p.38.

population. But neither Prime Minister Nehru nor Professor Sarabhai had any ambiguity of purpose: if Indians were to play a meaningful role in the community of nations, they must be second to none in the application of advanced technologies to their real-life problems.”²⁰⁶ At TERLS he provided “interface support” for payloads scientists, domestic and international, who came with different kinds of instruments to be lofted on sounding rockets and slowly began working on other subsystems and “jettisonable nose cones.” Working on nose cones brought him closer to the world of composite materials.

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Configuration of SLV-3

The four staged all solid SLV-3 was fueled by composite propellants. The stages were designated as S1, S2, S3 and S4. (see below figure), and also for the whole configuration of the stages (see appendix 2 and 3). Work on all four stages started simultaneously in Thumba. The lower stages S1 and S2 had specialized steel casing and the upper two had casing made up of fiber reinforced plastics (FRP)

The composite slurry which was directly poured into metal and fiber casings for setting had a mixture of ammonium perchlorate (70 percent), aluminum powder (15 percent), a mixture of other chemicals (5 percent) and a resin, the most important of all, that binds all of the substances together (10 percent). Though binders only occupy a small portion of the composite they determine the propellant grains’ storability, reliability, performance and efficiency.²⁰⁸

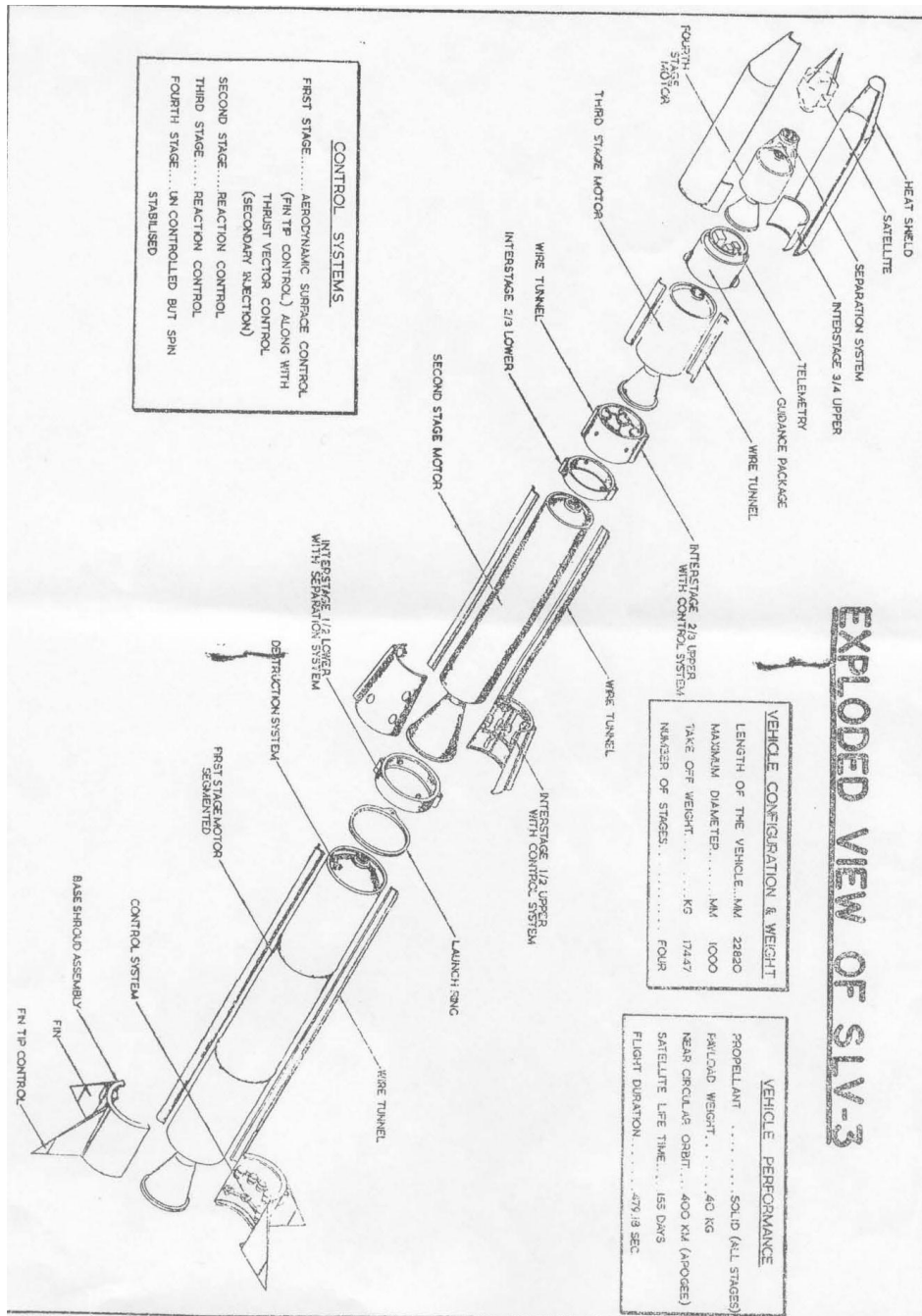
²⁰⁶ Ibid. p. 43.

²⁰⁷ Abdul Kalam, *Wings of Fire*, pp. 45-47.

²⁰⁸ Gopal Raj, *Reach for the Stars*, pp. 76 - 77

Figure 12: Exploded view of SLV-3²⁰⁹

Source: SLV-3 Project Bulletin



²⁰⁹ This view shows the segmented feature of the first stage (S1). In the Scout rocket the first stage was casted as a single motor.

The casing for the first and second stage was made up of 15 CDV 6 steel (French specification standard). It is a high quality steel made with small percentage of Manganese, Chromium, and Molybdenum. This steel was most coveted for rocket casings because of its excellent material properties: they are high strength; they could be easily welded and withstand high temperatures and pressure without cracking. Today their use is ubiquitous – in automobiles, aircraft and also in bicycles. The Indian space establishment got introduced to 15 CDV6 while license producing Centaure rockets in India. The first indigenous French rocket Diamant – A, that launched Asterix on November 26, 1965 from Hammaguir in Algeria, was entirely made of this steel.²¹⁰

Three engineers who pioneered the indigenous manufacture of solid propellants are Vasant Gowarikar, M.R. Krupp and A.E. Muthunayagam. The following paragraphs briefly describe their background and their contributions.²¹¹

Gowarikar received his chemical engineering degree in the UK and was also trained in tactical missiles at the Summerfield Research Station in Great Britain. It was during his time in the UK that he was invited by Sarabhai to join and help Indian space efforts. He joined ISRO in 1969 and began working at SSTC in Veli Hills. His experience at the new facility was a stark contrast to his training in UK:

I was the first to shift to Veli Hills (a new facility near Thumba for making solid boosters) from the church building (where early work on solid rockets first started). ...churning the solid propellants in a mixer.....one day Sarabhai dropped in my tiny room and was greeted by a snake chasing a rat, an all too familiar sight

²¹⁰ M.K. Mukherjee, “Study Report on The Possibilities of Reducing the Foreign Exchange Components of Indian-Made Centaure Rockets,” Space Science and Technology Center, Trivandrum. (undated), VSSC Library and Records Division.

²¹¹ Kurup’s contribution to Indian rocketry is very limited.

on Veli Hill in those days! “you would have missed such lively sights in England, wouldn’t you? Said he with a big grin, Yes Indeed, I said.the conversation would lead to a more pleasant experience of clearing all plans for a propellant complex.²¹²

A.E. Muthunayagam, another key engineer at ISRO, initiated the plan for a Static Test Evaluation Complex (STEX) in India to be established at SHAR. Today he is considered as the father of liquid propulsion in ISRO. He was the founder director of Liquid Propulsion Systems Center (LPSC), headquartered in Valiamala, Kerala. A Tamil Christian, born in the town of Nagercoil, 50 km from Thumba. After getting his bachelors in mechanical engineering from Madras University in 1960 he joined Indian Institute of Science for his Masters. He later moved on to Purdue University, USA to complete his PhD in Mechanical Engineering. He was interviewed by Sarabhai in the Spring of 1966 and he joined the April 1966 as a Divisional Head of SSTC. At this center he worked on all areas of propulsion for both launch vehicles and satellites. He acted as the Director of Propulsion Systems Group at VSSC and additionally as the program director of Auxiliary Propulsion Unit of ISRO. His early work was on developing solid propulsion technology for sounding rockets and was instrumental in the development of the first indigenous sounding rocket RH-75 that was first tested in November 1967. He later developed solid rocket motors for projects RH-100, RH-125, RH-200, RH-300 and RH560. He also contributed to the propulsion systems for all the SLV-3 vehicles. STEX was used for testing SLV-3 motors for performance and other things like vibration, thermal cycling, constant acceleration and spin. In the SLV-3 he made significant contributions specifically in the area of grain design and interior ballistic analysis, nozzle design and development and ignition system for lower stages. He was also responsible for three

²¹² Vasant Gowariker, “Reminiscences” in *Development of SLV-3: Retrospective*, p. 10.

control systems of SLV-3, namely, SITVC for the first stage, bipropellant RCS for the second stage, Mono-propellant RCS for the third stage were designed, developed and supplied to SLV-3 by propulsion group under Muthunayagams overall responsibility.²¹³

Shopping for Ideas and Hardware

Once the decision on propellants was taken, the initial enquires were made with the United States, France and Japan for purchasing them directly from vendors.²¹⁴ Indigenous efforts were taken only when the Indian engineers faced hurdles in getting access. Sarabhai personally wrote to Arnold Frutkin of NASA and arranged a visit for Kurup, Gowarkiar, and H.G.S. Murthy of TERLS. They visited United States in the Fall of 1971.²¹⁵ The purpose was to discuss the availability of propellant plant equipment with American suppliers. After visiting NASA installations and seeing American plant layouts, they asked for quotations from equipment suppliers which was necessary for budget estimates for Indian plant to be constructed at the new range, forty miles north of Madras (now Chennai). The team also showed interest in safety features and raw materials and final product analytical and evaluation equipment.²¹⁶ The trip was eye opener to all of them.

Gowarikar was instrumental in establishing the Propellant Fuel Complex (PFC) at Thumba for scaling up production of polymers before massive industrial production. The building of PFC started in 1972. He was also influential in constituting the Solid

²¹³ Ashok Maharaj, interview with A.E. Muthunayagam, April 15, 2011.

²¹⁴ Hideo Itokawa, the father of Japanese rocketry, was appointed by Sarabhai as a consultant. For his recollections and consultant work in India see Hideo Itokawa, *My Days in India*, translation from Japanese. (undated). I would like to thank Manoranjan Rao for sharing his personal copy with me.

²¹⁵ American Consulate, Madras to American embassy, New Delhi, "Visit of TERLS scientists to US, 02 August 1970," Subject Numerical Files, 1970-73, box 2962, NARA II.

²¹⁶ American Embassy, New Delhi to Secretary of State, July 1970, "Equipment for Rocket Propellant Production," Subject Numerical Files, 1970-73, box 2962, NARA II.

Propellant Space Booster Plant (SPROB) at Sriharikota. The facility was built using mostly indigenous sources.²¹⁷ SPROB was commissioned in March 1977.

Kurup, head of the Rocket Propellant Plant (RPP) of TERLS, visited the United States in October 1971. During his two week tour he visited Wallops Station, Kennedy Space Center, Arnold Engineering, Rocketdyne, Aerojet General and United Technology Center, for two weeks in October 1971.²¹⁸ He preferred US components and subsystems to those from other countries. During his visit he requested a continuous supply of polysulfide and carboxyl terminated polybutadiene from Thiokol Corp, one of the binders of the solid fuel propellant. US Munitions Control regulations posed restriction on the transfer of this compound leaving Kurup to indigenously produce them at Thumba.²¹⁹ He also became one of the key engineers to design and test Rohini 560, which became a workhorse for testing various SLV -3 subsystems. RH 560 was 7.6 meters long, 2 stage; max diameter 560 cm; capable of launching 80 kilos to 420 km altitude (see below figure). Another team comprising of S. Srinivasan, M.K. Abdul Majeed and J.D.A Subramanian, engineers at ISRO, visited various space science and technology centers in Japan learning about the “development of Japanese rocket motors, separation and destruct systems used for Mu rockets and the facilities existing at NASDA²²⁰

²¹⁷ Gopal Raj, in his book mentions that for building the facility foreign companies demanded Rs. 50 crore. See this quote to be enormous, Gowarkiar and his group decided to build the facility with just eight corers with just eighty lakhs in foreign exchange. The SPROB proposal was formally cleared in 1971 with a sanctioned cost of Rs 7.92 crore, see Gopal Raj, *Reach for the Stars*, p. 85.

²¹⁸ American Embassy, New Delhi to Secretary of State, 30 September 1970, “Visit of Kurup to USA,” RG 59, General Records of the Department of State, Subject Numerical Files, 1970-1973, box 2920, NARA II.

²¹⁹ American Embassy, New Delhi to Department of State, March 21, 1973, “Trip Report – Sciatt Visit to Madras, Trivandrum and Ahmedabad – February 14 to 21, 1973,” RG 59, General Records of the Department of State, Subject Numerical Files, 1970-1973, Science, box 2919, NARA II.

²²⁰ Vikram Sarabhai Space Center, *SLV Project Bulletin* 1, no. 2 (February, 1974).



Figure 13: RH 560 on a launch pad

After Kalam was appointed as Project Manager of SLV-3, a review of the project was undertaken and milestones were listed. How to get the hardware for a launch vehicle? For this a team was constituted with Srinivasan as Chairman and V. Manoharan as the convener “to decide on material choice, and fabrication route.” Many at the space establishment advocated for in house production, meaning that the space establishment took responsibility for manufacturing hardware rather than contracting with industry,

They were overruled. “We in the project looked beyond SLV-3 and taking into account obvious advantages of industry route in terms of productivity, professionalism and infrastructure availability, we preferred industry mode. Ultimately it was decided to go for industry mode of realization.” A specialist team headed by Kalam held discussions with prospective industries and Initially four industries were chosen. The involvement of industries in the space program was a visionary decision. The ISRO-Industry partnership initiated during SLV-3 has grown into a lasting relationship.²²¹

²²¹ V. Manoharan, “Spartan Memories,” in *Development of SLV-3: Retrospective*, p. 77.

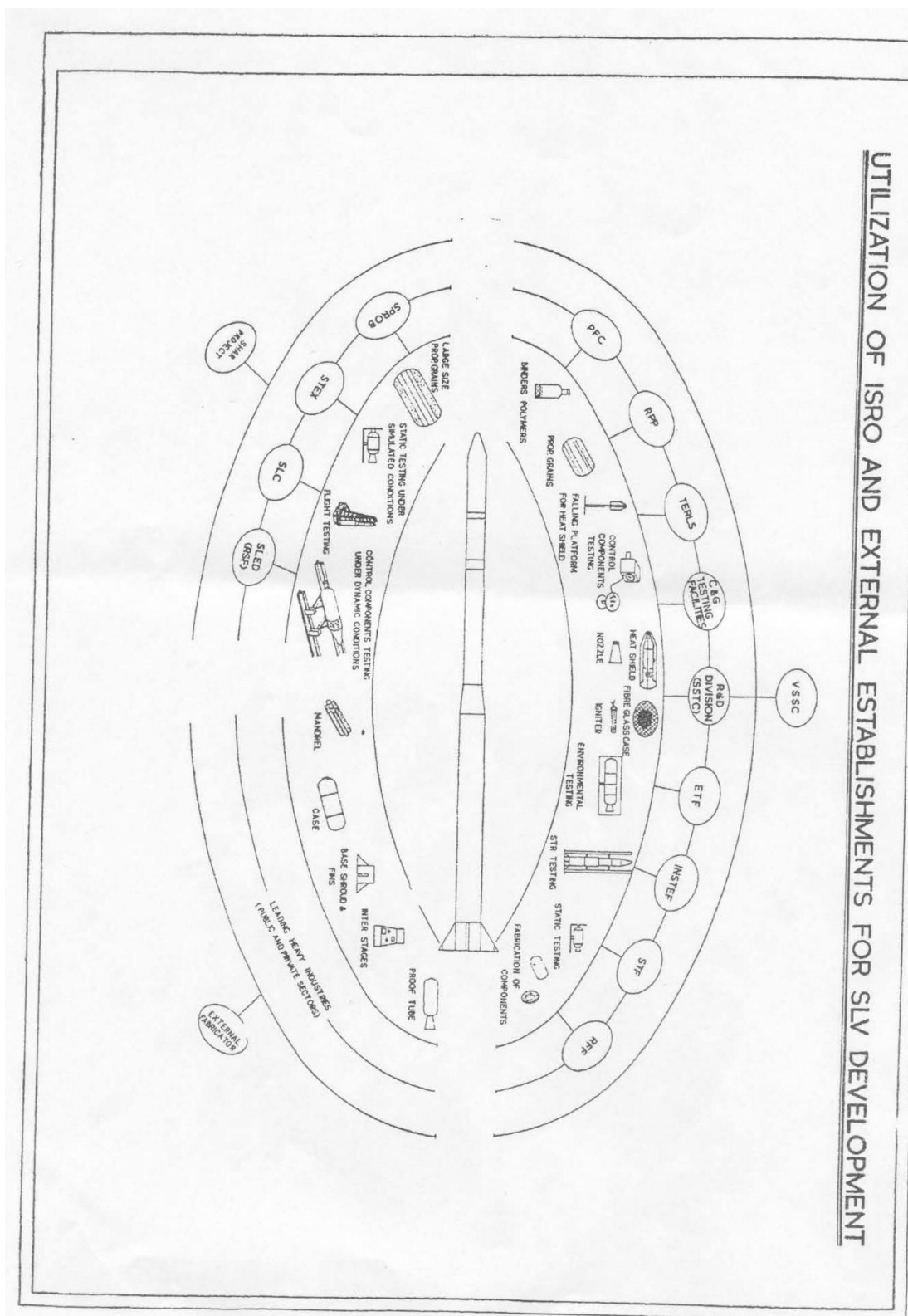


Figure: 15 Utilization of ISRO and external establishment for SLV development.

Source: SLV—Project Bulletin, ISRO.

For establishing STEX, Muthunayagam visited the US for information and a visit to Jet Propulsion Lab (JPL) was arranged by Satish Dhawan. They both visited the JPL facility. “but the US took a tough stand on any sort of help in establishing solid motor test facilities in India” The Indians approached the French and a cooperation was initiated with Societe Europeene de Propulsion (now Snecma moteurs’ rocket engine division). For High Altitude Test facilities (HAT) which could stimulate near vacuum conditions, ISRO received help from the German space agency (DFVLR). When an American company was prevented from supplying a 16 ton vibration table (shake table), a British company stepped in.

The outer casing of the upper two stages (S3 and S4) are made of composite fibers. To gain expertise, Kalam and H.G.S Murthy sent C.R. Sathya, of the Fiber Reinforced Plastics Division (FRP), to NASA’s Wallops Island to look at Scout’s upper stages in the year 1971. The visit offered him a valuable insight on strength of glass fibers. When these fibers are tightly woven in the form of a vessel they could form suitable motor cases capable of withstanding high pressure, “the visit opened my eyes” says Sathya.²²² Also, another engineer P.N. Subramanian, dedicated his life to FRP at VSSC. The first seminar on FRP composites inaugurated by C. Achutha Menon, Chief Minister of Kerala, in the Presence of Sarabhai gave the necessary confidence to develop an FRP casing for the upper stages of satellite launch vehicles. In the meantime C.R. Sathya who had taken over as Deputy. Head of FRP division could obtain a cut piece of the FRP casing developed by the Aerojet Corporation of USA. This visit provided him many clues on how to approach the design of the joints

²²² C.R. Sathya, “SLV-3: A Spring Board for Composites,” in *Development of SLV-3: Retrospective*, p. 30.

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²²³ C.R. Sathya, “SLV-3: A Spring Board for Composites,” in *Development of SLV-3: Retrospective*, p. 30.

filament wound casing., the configurations – counters etc, insulation plan and so on.²²⁴

(for a closer look at the 4th stage that used FRP, see the image below)

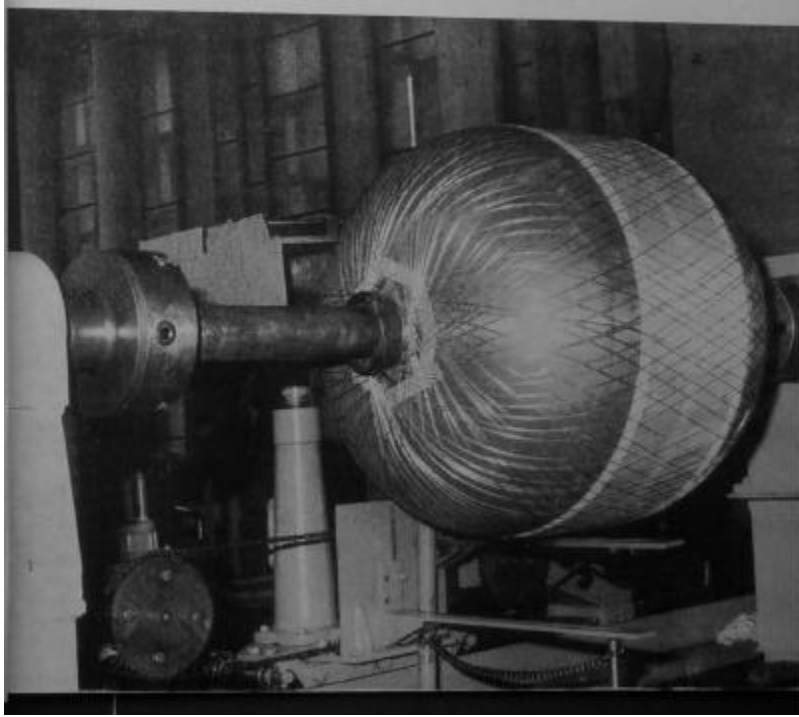


Figure 16: Filament Winding Machine for the fourth stage of SLV-3.

Source: Countdown

Frutkin remembers seeing a filament winding machine when he visited Thumba in the early seventies.

“When I visited they showed me what they were doing. There was a filament spinning technology which is used in the casings of solid rockets and [...]they were working with that. They’d gotten it from the French. Then there is the casting of the solid propellant itself. They have gotten into that. Then I remember one of the critical items of technology that they needed in developing the rocket

²²⁴ Ibid.

was a shake table. They're very large structures that I think...are designed to simulate the high vibration regimen in the launch phase, and they shake rockets to see what they –they have to build to withstand that terrific vibration. They applied to get shake tables in this country, and I'm quite positive they were denied, but they did get them from somebody else.²²⁵

The FRP Division was created in 1971 and Kalam also proposed the setting up of Reinforced Plastics Centre (REPLACE). It was commissioned in November 1976.

Control and Guidance

When rocket takes off from a launch pad, it is subjected to a variety of internal stresses due to the thrust from the stage motors and aerodynamic pressures during the course of its flight. If there is no internal mechanism to neutralize the 'disturbances' and maintain the rockets orientation (in scientific terms 'attitude') it could deviate from its nominal trajectory, and could potentially break up. A control and guidance system (CGS) helps the rocket to overcome these disturbances and steers the rocket to a desired target -- be it injecting a satellite to a predetermined orbit or to deliver a bomb, conventional or nuclear, to a precise radius. The sophistication of the CGS package varies depending on the rocket and payload it is carrying. For example, a sounding rocket with an experimental payload to study the upper atmosphere is stabilized either by spinning the rocket once aloft or by using fins fitted on the rocket frame, or a combination of both. At the other extreme, a rocket carrying a communication satellite, weighing a few tons, to be placed in a geosynchronous orbit requires a more sophisticated CGS.

²²⁵ Rebecca Wright, interview with Arnold Frutkin, 8 March 2002.
http://www.jsc.nasa.gov/history/oral_histories/NASA_HQ/Administrators/FrutkinAW/FrutkinAW_3-8-02.pdf (Accessed on February 20, 2011)

When Vikram Sarabhai planned a simple launch vehicle during the late sixties, an optimum CGS for the rocket was calculated in parallel and a team was created under the headship of Suresh Chandra Gupta to take on the technological challenge. S.C. Gupta received his doctorate in electrical engineering from University of Pennsylvania, USA, in 1964 and was personally interviewed by Vikram Sarabhai to join SSTC to lead the competence building and indigenization of Control, Guidance and Instrumentation system. However, the basic infrastructure for manufacturing precision parts and assembling a CGS package was either rudimentary or non-existent. Initial negotiations with the United States for buying the system “off the shelf” did not materialize, “they refused to provide even catalogues about their Gyros,” says Gupta. This left the team to fabricate and assemble a flight worthy package with help from France and West Germany.²²⁶

Internally the CGS package consists of the following subsystems: stage Control Power Plants (CPP), On-board Digital Processor (OBP), Inertial Measurement Unit (IMU) and Rate Gyro Package (RGP); all of these subsystems are made of precision parts and they have to act in unison to guide the launch vehicle to its desired target. When the task of building the CGS indigenously was decided, a Control, Guidance and Instrumentation Division (CGI), Aerodynamic Division (ARD) and Structural Engineering Division (STR) was established at the Vikram Sarabhai Space Center (VSSC). Later a separate ISRO Inertial Systems Unit (IISU) was formed and N. Vedachalam was made the first director of the unit with Gupta as the overall head. The Atomic Energy Commission offered Rs. 1.25 crore to establish the Precision Instruments

²²⁶ Sagem of France supplied the Inertial Measurement Unit (IMU) for the first flights of the SLV-3, see Gopal Raj, *Reach for the Stars*, p. 149.

Laboratory (PIL) at ISRO to help Gupta's team. Parts were procured from European countries, mainly Switzerland, to equip the new laboratory.

Gupta's team early on decided to fly SLV-3 using the highly complex inertial guidance system. However, the plan was dropped owing to the complexity of the subsystems and the technological challenges it posed. In its place, a less complicated open-loop guidance system that offered a preprogrammed trajectory was chosen.²²⁷

Link Between the Space Program and the Defense Establishment

Viewing the history of India's space program since the 1960s one can visibly see the rhetorical message of 'space for socio-economic development' embedded in the functioning and the execution of space activities. Conversion of civilian rockets for military missiles, though mentioned at times, was never pursued with dedicated interest. During the early phase under Sarabhai's leadership, fearing the denial of technological exchange with advanced countries, the civilian program was deliberately kept separate from defense related rocketry.

Cross-fertilization between the Defense Research Development Organization (DRDO) formed in 1958, and the civilian space establishment never really attained significance until the start of IGMDP. However it would be misleading to say that the defense establishment and the civilian space program were independent. With a very small pool of scientists and engineers, constant traffic was happening between the Department of Atomic Energy, the space, and the defense establishment. In an interview by Amrita Shah, Pramod Kale says that "the lines of communication between the two were far from closed...we were very clear that space was for peaceful purposes but we

²²⁷ Vikram Sarabhai Space Center, *SLV 3 Project Bulletin* 1, no. 2 (February, 1974). p. 13.

had the capability that could help and if the government wanted it, it was there. Defense people would come to see us and vice versa. For us it was very open.”²²⁸

An early example of cooperation between defense and space is highlighted in Abdul Kalam’s autobiography. Kalam worked on Rocket Assisted Take Off (RATO) for military aircraft in the Himalayan region before being assigned for the SLV-3 project. Working on RATO brought him closer to the defense establishment and he became a member of the Ministry of Defense’s “Missile Panel” along with V.S. Narayanan, physicist and an Army general who was given the responsibility of producing an ICBM during the 1960s.²²⁹

A space program for exclusive socio-economic benefits however got tipped toward a ballistic missile ability owing to geopolitical situation. The reorganization of the space program also created a more conducive environment for linking the space program toward strategic needs. Sarabhai’s pacifism ended peacefully after his death and Indira Gandhi’s “men”²³⁰ had ample elbow room with State largesse to develop a launch vehicle that could carry both a satellite and eventually a nuclear bomb. The increasing collusion of technologists was also noted by the then Ambassador to India Patrick Moynihan

The Indian Government is progressively increasing its control over technology and technologists in India....conversely, the technologists are looking for more political power. ...Most Indian technologists prefer to deal with the USA.... The Department of Atomic Energy, Space, and Electronics have Prime Minister Indira Gandhi as Minister. Reporting to her are three experienced technologists: Homi Sethna, Secretary of the GOI for Atomic Energy and Chairman of the Atomic Energy Commission, Dr. Satish Dhawan, Secretary of the GOI for Space, and

²²⁸ Shah, *Vikram Sarabhai*, p. 132.

²²⁹ Kalam, *Wings of Fire*, p. 53.

²³⁰ I call them Indira’s men because Dhawan, Brahm Prakash, MGK Menon, had direct link with prime ministers office (PMO), a privilege only Bhabha had with Nehru.

Chairman of the Space Commission, MGK Menon, Secretary of the Department of Electronics and Chairman of Electronics Commission (also director of TIFR Bombay). Although increasing in authority, none of these three yet match the deceased Homi Bhabha or Vikram Sarabhai.²³¹

The 1971 Indo-Pakistan war brought a lot of political pressure (see below) on the space establishment toward developing a launch vehicle that could be converted to a ballistic missile. After the Pokhran nuclear test of 1974, there was increasing momentum to create a nuclear deterrent. Interrogating the development of SLV-3, shows us that the walls of the space establishment was porous and often there was close interaction between the defense and space establishment.

Satish Dhawan, Chairman of the Indian Space Research Organization, was the one chosen to visit the Pokhran I nuclear test site along with Indira Gandhi in December of 1974 (see figure 17)²³²

²³¹ Patrick Moynihan, American Embassy, New Delhi to Department of State, "Science and Technological Affairs in India – political aspects," April 2, 1973, RG 59, General Records of the Department of State, Subject Numeric Files, 1970-73, folder SCI 2 - India, box 2919, NARA II.

²³² This fact has not been highlighted by any published work.



Figure 17: Satish Dhawan (third from right) behind Indira Gandhi.

source: Weapons of Peace, Raj Chengappa.

Dhawan made public statements soon after the Pokhran nuclear test that the space establishment had the capability to produce an IRBM if the Government gave a go ahead (see below). His presence at the test site along with dignitaries was not a random choice

by Indira Gandhi. The presence of Dhawan and the increasing funding the space establishment, especially VSSC and SHAR received during the SLV-phase, raises puzzling questions about the nature of the dichotomy that has been etched in scholarly works on the Indian space program and how it was exhibited publicly -- that the space program and the missile program are separate entities. This point was again made by Kalam during my interview with him “ defense research in missiles and space programs for launch vehicles are separate and space had nothing to do with missile efforts, *even now.*”²³³ (emphasis mine)

Here is an interesting interview conducted by Subramanian Swamy, a member of the parliament belonging to the Jana Sangh political party. The questioning by Swamy, shows how informed his party was about rocketry.

Q: Does India produce its own solid propellant?

A: Yes

Q: What is the specific Impulse of this propellant?

A: 240 seconds

Q: Is that enough to Generate 70, 000 lbs of Thrust
for an IRBM?

²³³ Ashok Maharaj, interview with Abdul Kalam, January 18, 2009.

A: Yes

Q: You have Developed an Inertial Guidance System?

A: Yes, we have, for satellite launching

Q: If you have the propellant of adequate specific impulse and the inertial guidance system, you have everything for an IRBM?

A: Yes, we do. If the Government desires us to produce an IRBM we can.

Seeing this interview appear in a newspaper, US Ambassador in India Patrick Moynihan and his faithful aide David Schneider sent a report to Secretary of State giving details about specific impulse and stating that “If the specific impulse is above 230, then an IRBM capability is achieved. India has thus attained 10 seconds more than the required minimum impulse.” Embassy also commented, “this is the first reference in print that we remember seeing where a military use for India’s peaceful space program has been mentioned by a senior Indian official.”²³⁴

Chronologically moving further, in January 1975 M.G.K Menon, cosmic ray physicist, director of TIFR, and who became the “raja of electronics” in India was posted

²³⁴ David Shneider, American Embassy, New Delhi to Secretary of State, “Indian IRBM’s,” 10 July 1974.
<http://aad.archives.gov/aad/createpdf?rid=115768&dt=2474&dl=1345> (accessed on 1st March, 2011)

as the director of DRDL and DRDO. He appointed a review committee under the chairmanship of Brahma Prakash, to emulate the work carried out in the Devil Project (a surface to surface missile) and Valiant. Kalam and MGK Menon met at DRDL on the 1st and 2nd of Jan 1975 and March was the final meeting.” In the meeting Menon, when the talk of terminating Devil and Valiant came up, said, “I tried to tailor the policy to have a commonality of technology so that without too much more effort you could produce an entire family of missiles with the same basic pieces like a mechano or Lego set from which you could build all sorts of things.”²³⁵ The early idea of an IGMDP is hinted at here.

In the field of guidance packages too, we see close relations between the defense establishment and ISRO. The inertial guidance team at VSSC met with a difficult problem when producing a highly sensitive component “yaw and outer roll gimbal in aluminium alloy.” The team narrowed down a solution and sought help outside VSSC. On 2nd September 1976, S. Dhawan contacted Air Marshall S.J. Dastur, the Chairman of Hindustan Aeronautics Division, Koraput. On 13th September 1976, Abdul Kalam, who was then the Project Director SLV-3, contacted V.S. Arunachalam, Defence Metallurgical Research Laboratory (DMRL) highlighting the problems and suggesting actions. The ISRO team of Sir M.C. Mittal and Sir George Koshy, together with K. Suseelan Nair, R. Jayaraman and I. Raja Rao of MAC foundry and under the able guidance of M.K. Madhekar, B.K. Sarkar and M.K. Mukherjee resolved the technical issues and developed the investment casting process technology for this flight critical component within the required time schedule at HAL, Koraput. “The team also received

²³⁵ See Robert Anderson, Robert S. Anderson, *Nucleus and Nation: Scientists, International Networks, and Power in India* (Chicago: The University of Chicago Press, 2010), p. 736.

unstinted support from Arunachalam and his team at DMRL. Kalam, Brahm Prakash, Dhawan, and Air Marshal Dastur and senior members from ISRO and HAL witnessed the successful demonstration of this technology.”²³⁶

Launch Vehicle Development after SLV -3

On the civilian side, experience gained in building the SLV-3 was gradually increased for heavier rockets. The follow on Augmented Satellite Launch Vehicle (ASLV), had two strap-on boosters added to the existing SLV-3. ASLV had the capability to place a 150 kg satellite in low earth orbit. It was followed by the Polar Satellite launch Vehicle (PSLV). PSLV is the work horse that today can launch a satellite of almost two tons into low earth orbit. Technological denial and tight controls on technology transfer, through the Missile Technology Control Regime, (MTCR), were implemented after the successful launch of the Agni missile in 1989. The technology controls that were put in place delayed India’s ambitious project to build the Geosynchronous Satellite Launch Vehicle for placing heavier application satellites in geosynchronous orbit.²³⁷

²³⁶ M.C. Mittal and K. Suseelan Nair, “Yaw and Outer Roll Gimbal Investment Casting Development for IMU of SLV-3,” in *Development of SLV-3: Retrospective*, pp. 116-117.

²³⁷ For a closer look on the impact of technology controls on the Indian space and missile developments see Angathevar Baskaran, *Technology Development in India's Space Programme 1965-1995: The Impact of the Missile Technology Control Regime*, Thesis, (University of Sussex, 1998); Angathevar Baskaran, The Impact of Export Controls on Indigenous Technology Development in India's Space Programme,” *International Studies* 38, no. 2 (2001):155-171.

Table 4: Evolution of India's rocket program

Name	Stages	Length Overall (cm)	Max.Boxy diameter (cm)	Weight at launch (kg)	Payload Kg.	Launch angle in degrees	Peak altitude
Rohini 75 TR	1	1019	7.5	6.85	1	65	5
Rohini 75	1	1512	7.5	10	1	65	9
Rohini 100	1	2027	10	24.55	3.2	65	14
Menaka 1 (Rohini 100 + Dart)	2	2889	10	25.88	4.15	82	58
Rohini 125	1	1660	12.2	27.88	4	65	11
Rohini 125 + Rohini 75	2	3172	12.2	37.3	1.1	85	93
Rohini 125+ Rohini 100	2	3687	12.2	51	3.2	85	100
Menaka II (Rohini 125 + Rohini 125)	2	3789	12.2	58.8	3.5	85	100
Indian Centaure	2	5900	30.5	530	57.3	82	136
Rohini 300	1	4850	31.6	420	40	85	100
Rohini 560	2	7463	56	1391	100	80	334
Rohini SLV-3	4	194,440	100	17.337	30 (in orbit)	80	400 (in orbit)

Source: Theo Pirard, "India in Space," *Space Flight*, (March 1975): 94-98

Table 5: SLV-3 Vehicle Stages²³⁸

1 st Stage	1000 mm diameter; 10.04 meters long; 15 CDV 6 steel body; 8951 kg of propellant; 43021 kg of average thrust; 50 seconds burning time; and 10956 kg in weight	Kurup – RPP used the existing facility for making Centaure and gradually scaled the design. PBAN was the resin.
2 nd Stage	800 mm diameter; 6.5 meters long; 15 CDV 6 steel body; 3250 kg of propellant; 19888 kg of average thrust; 40 seconds burning time; and 4139 kg, in weight	RPP. Expansion of the existing facility was done to accommodate the SLV-3 requirement
3 rd Stage	800 mm diameter; 2.5 meters long; Fiber glass motor body; 1076.8 kg of propellant; 6559 kg of average thrust; 39 sec burning time and 1284.7 kg in weight	Gowarikar. Team at Propellant Engineering division. (PED)
4 th Stage	650 mm diameter; 1.6 meters long; fiber glass motor body; 264 kg of propellant, 2123 kg of average thrust; 31.5 sec burning time and 300 kg in weight	Kalam was incharge
Heat Shield	800 mm diameter; and 2885 mm long. It protects 4 th stage and satellite from aero dynamic heating.	

²³⁸ Ibid

Table 6: SLV Configuration²³⁹

Number of Stages	4
Stage Motors	Solid
Length of the vehicle	22.8 Meters
Maximum Diameter	1 meter
Lift of Weight	17, 100 kg
Vehicle Capability	
Payload (Satellite)	Weight 40 kg
Orbit	280 km * 560 km (elliptic)
Satellite life time	100 days (minimum)
Flight duration before injection of satellite	468.97 second
Control Systems	
First Stage	Aerodynamic Fin Tip Control (FTC)along with Secondary Injection Thrust Vector Control (SITVC)
Second Stage	Reaction Control
Third Stage	Reaction Control
Fourth Stage	Spin Stabilized

²³⁹ Adapted from Vikram Sarabhai Space Center, *SLV Project Bulletin* 1, no. 1 (1973).

Chapter IV

Polyvalent Meanings of Satellite Broadcast in Rural India: NASA and the Satellite Instructional Television Experiment (SITE)

The 1970s was a time of global crisis on the political, economic and social fronts. On the technological side, however, particularly in relation to everyday life, the decade was filled with major breakthroughs beginning with bar codes and ending with the iconic Sony Walkman.²⁴⁰ For the first time, even poor people living in some developing regions came face to face with a technology—direct broadcast television delivered by satellite—that would alter their lives significantly. Deemed improbable in the early sixties, such communications, on a limited basis, became a reality during the mid seventies owing to major developments in the transmitting power of satellites. Developing countries could now envision bypassing the difficult stages of installing expensive land-based microwave networks and develop a satellite-based network that used augmented television sets with inexpensive antennas to receive signals directly from satellites. The possibility that developing regions might leapfrog into “modernity” through this revolutionary technology captured the imagination of technocrats and policy makers. In their view, this new medium offered the opportunity to shape the “habits” of millions of people and remove the pool of ignorance that was detrimental to progress. The United States, in alliance with other countries, pursued projects in India, Puerto Rico, Brazil and 27 other nations, making them laboratories to test the effectiveness of using satellite broadcasting

²⁴⁰ Niall Ferguson, et al., *The Shock of the Global: The 1970s in Perspective* (Cambridge, Mass: Belknap Press of Harvard University Press, 2010).

for mass media, and helping engineers to test novel technologies and determine orbit and spectrum allocations for future application satellites. Seeing the utility value of the satellite for development needs, many developing countries established ground satellite terminals for receiving signals and in some countries for a full-fledged National Satellite Systems.

The most spectacular direct broadcasting experiment conducted using the most sophisticated satellite of the time ATS-F (which later became ATS-6) was the Satellite Instructional Television Experiment (SITE). Close to 2400 Indian villages, reaching a total of 2.8 million people a day, in different geographic regions across India received instructional television programs directly from this satellite. The agreement for SITE was signed between NASA and India's Department of Atomic Energy (DAE) on September 18, 1969. The project was executed from August 1975 to July 1976 and received a great deal of media attention in the country. It was touted as a massive experiment in social engineering and was hailed by some enthusiasts as the world's largest sociological experiment.²⁴¹ The British science writer Arthur C. Clarke called it the "greatest communications experiment in history."²⁴² Praise for the intangible benefits of the SITE project was perhaps best summarized in a report to the United Nations Committee on Peaceful Uses of Outer Space:

SITE can be considered a pace-setter and fore-runner of satellite television systems particularly of those meant for development. It is an example of technological and psychological emancipation of the developing world. Its most important element was the commitment and dedication of all people and organizations involved to the one overriding goal of rural development in India.

²⁴¹ K. Kasturirangan, "Share and Care for a Better World—The Engine for Future of Space," *Acta Astronautica* 54, nos. 11-12 (June 2004): 867. The author was the former Chairman of ISRO.

²⁴² Yash Pal, "A Visitor to the Village," *Bulletin of the Atomic Scientists* 33, no.1 (January 1977), p. 55. Arthur C. Clark served as a consultant to the SITE project since its inception.

From this follows the crucial role of motivation and cooperation for the success of complex and challenging tasks.²⁴³

The official Indian reaction to SITE was very positive. The immediate visible results of the broadcast, as cited by project evaluators in the rural clusters, was improved school attendance, increased concern for proper nutrition and an awareness of sanitation and personal hygiene as methods of disease prevention. One of the unanticipated benefits of the program was the electrification of numerous villages, a prerequisite for television reception.²⁴⁴ For the Indians, the visual demonstration galvanized public opinion in favor of a space program focused on socio-economic needs. It helped the country gain competence in using satellites for mass communication and was a systems management lesson for managing Indian National Satellite (INSAT) systems.²⁴⁵ SITE played an important role in the development of mass media in India. The story also throws light on the origins and growth of the electronics industry in India and the proliferation of firms that manufactured televisions and associated electronic components, and the establishment of television studios for various programs – educational and entertainment. These are the immediate visible manifestation of India's tryst with this evolving medium. The legacy of SITE can still be seen today when one watches educational programs sponsored by the University Grants Commission (UGC) that are broadcast on national television channels on a regular basis. ISRO's recent launching of Educational

²⁴³ "Report on the SITE Winter School," *UN Document No. A/AC/105/177*, United Nations Committee on the Peaceful Uses of Outer Space (December 2, 1976), p. 13.

²⁴⁴ "World Wide Space Activities," Report Prepared for the Subcommittee on Space Science and Applications of the Committee on Science and Technology U.S. House of Representatives, Ninety –Fifth Congress, First Session (September 1977), p. 404.

²⁴⁵ Kiran Karnik, "Societal Benefits of Space Technology," *Acta Astronautica* 19, no. 9 (September 1989): 771-777.

Satellite (EDUSAT) in 2004, a satellite designed exclusively for educational needs, can be traced back to the success of the SITE project.

SITE has not received much scholarly attention, though there are numerous reports on different aspects of the SITE project produced by the United Nations, the Indian space establishment, NASA and others. The existing literature focuses either on the technical aspects of the project -- satellites, ground stations, television sets etc. -- or on the organizational and evaluation part focusing on how the project was implemented on the ground and its outcome.²⁴⁶ The existing narrative takes SITE to be a logical move by a developing nation to use satellites to reach the rural masses and shows how NASA played a philanthropic role in achieving this aim. Complementing the standard narrative this paper contextualizes the SITE project by bringing in the broader currents of the Cold War to reveal the motivations and justifications for initiating a satellite project in India and exposes the polyvalent meanings it encapsulated when direct broadcasting was finally actualized between (August 1975—July 1976).²⁴⁷

More than a decade went toward planning the SITE program. While Arnold Frutkin and Vikram Sarabhai orchestrated the program during the development stages, a host of actors both national and international entered the scene to implement the program

²⁴⁶ Romesh Chander, and Kiran Karnik, *Planning for Satellite Broadcasting: The Indian Instructional Television Experiment*, (Paris: Unesco, 1976); Srinivas R. Melkote, Peter Shields, and Binod C. Agrawal, *International Satellite Broadcasting in South Asia: Political, Economic, and Cultural Implications* (Lanham, Md.: University Press of America, 1998); Binod C. Agrawal, *Social Impact of SITE on Adults* (Ahmedabad: Indian Space Research Organization, 1977); *The SITE Experience* (Paris: Unesco, 1983); *Satellite Instructional Television Experiment: SITE Winter School, January 16-28, 1976* (Ahmedabad: Space Applications Centre, Indian Space Research Organization, 1976). Most of the references cited here are studies conducted by government and non-governmental organizations, a comprehensive monograph on this project linking the project to the broader Cold War framework is yet to be published.

²⁴⁷ I resort to the term polyvalent here to indicate the multiple meanings it evoked to different social groups. I borrow this frame of analysis from the classic article on bicycles by Trevor J. Pinch and Wiebe E. Bijker, The Social Construction of Facts and Artifacts: Or How the Sociology of Science and Sociology of Technology Might Benefit Each Other, in Wiebe E. Bijker, *The Social Construction of Technological Systems: New Directions in the Sociology and History of Technology* (Cambridge: MIT Press, 1989).

on the ground. As the concept of educational television using geostationary satellites evolved during the mid sixties along with the immense potential it augured for reaching different regions of the globe to spread the gospel of modernization, the United Nations, the Ford Foundation, and the United States State Department through the Agency for International Development (AID) got involved by providing funds and experts for establishing the infrastructure. Technical assistance was also received through an “expert contract” from Hughes Aerospace Corporation, through the International Telecommunications Union (ITU). On the engineering side alone close to 12 to 14 man years of technical training was given to Indian scientists and engineers at NASA facilities.²⁴⁸ From the NASA side the program, apart from Arnold Frutkin, it was organized by J.E. Miller – SITE Program Manger, Howard Galloway, Resident Representative during SITE operation, both from GSFC, and Leonard Jaffe from NASA Headquarters. Key actors on the Indian side who managed different aspects of SITE included, E.V. Chitnis, overall Program Manger of SITE; Pramod Kale, scientist engineer who became the Project Manager –Electronics and TV hardware for the SITE project; Yash Pal – Director of the Space Applications Center (SAC), Ahmedabad; Binod C. Agrawal, an anthropologist who did all the sociological evaluation of SITE during and after its completion, and P. Krishnamoorthy, software program manger of SITE. Through all of their guidance and expert advice the planning for SITE gained momentum and the key actors channeled the Indian bureaucracy to create exclusive government agencies and units in the field of instructional, educational and commercial television in India. Initially located under the Indian Department of Atomic Energy (DAE) and

²⁴⁸ Clifford Block, et.al., “A Case Study of India’s Satellite Instructional Television Project,” *AID Report* (January 1977), p. 4.

unfettered by bureaucratic red tape, the Indian space officials had ample elbow room to devise, plan and orchestrate the entire program. Seeing the future of communication to be based on satellites, Indira Gandhi, Minister for Information and Broadcasting (MIB) in Lal Bahadur Shastri's cabinet and later as the Prime Minister of India supported developing communication networks for reaching the rural people of India.²⁴⁹

Geosynchronous Orbits and Geopolitics

Arthur C. Clarke, the father of the modern concept of satellite communications, first conceptualized the idea of a geosynchronous satellite for broadcasting purposes in a trade journal in 1945.²⁵⁰ In the geosynchronous orbit the satellite matches the Earth's 24 hour rotation, in short, for a viewer in earth it appears stationary 24/7. By the early 1960s American communication satellites like ECHO, TELSTAR, and RELAY were developed to transmit communications to different parts of the world.²⁵¹ The technological, cultural and political possibilities offered by these satellites prompted the U.S. military, Government, and private corporations to develop communications satellites to expand America's global outreach. The aim was to create a "single global system" benefiting the entire world but also serving the Cold War interests of the United States.²⁵² However, a huge technological gulf existed between Clarke's prediction and the successful implementation of a geosynchronous satellite for communication purposes. AT&T, the American telecommunication giant, which pioneered early research activity on passive

²⁴⁹ Indira Gandhi used the new medium of television extensively for projecting her political image, often the State owned Doordarshan, the exclusive Department created for national television was often called satirically as "Indira Darshan," see Shanti Kumar, *Gandhi Meets Primetime: Globalization and Nationalism in Indian Television* (Urbana, Ill: University of Illinois Press, 2005).

²⁵⁰ Arthur C. Clarke, "Extra-Terrestrial Relays: Can Rocket Stations Give World-wide Radio Coverage," *Wireless World* (October 1945): 305-308.

²⁵¹ For a detailed account of early communication satellites see David J. Whalen, *The Origins of Satellite Communications, 1945-1965* (Washington [D.C.]: Smithsonian Institution Press, 2002).

²⁵² Hugh R. Slotten, "Satellite Communications, Globalization and the Cold War," *Technology and Culture* 43, (April 2002): 315-350.

and active satellites leaned toward low earth orbiting (LEO) communication satellite systems because of the technological glitches associated with geosynchronous satellites. Even during the early 1960s, scientists estimated the weight of the satellite to be of the order of 9 tons.²⁵³ A RAND report indicated that “radiated power, weight and boost requirements [...] except for the cases of the very low altitude and very small coverage are well beyond man’s current technical achievements.”²⁵⁴ Hughes Aerospace, based in California, was the only private corporation that was positive about establishing a global system based on geosynchronous satellite. In spite of the growing speculation regarding the technological feasibility of a geostationary satellite, the Kennedy Administration clearly saw the potential of using geostationary communication satellites to win the hearts and minds of millions of people living in different geographic regions of the globe. Technologically a system based on geosynchronous satellites did not demand expensive ground stations like the one demanded by a network of low earth orbiting satellites. This opened the opportunity for many developed and developing countries to participate in the evolving global system by investing initially in ground stations and moving up to create their own domestic satellite systems.

²⁵³ G.M. Ives, “Television Broadcasting from Satellites,” *Astronautics* (June 1962), p. 87.

²⁵⁴ C.M. Crain, “Broadcasting from Satellites,” the RAND Corporation, Paper P-2395 (August 3, 1961), p. 12. Another study by Leland Johnson for the Rand Corporation also gave a negative picture of the potential of broadcasting using satellites. He stated that “on economic grounds the use of satellite holds much less promise” and the “potential economic advantages of satellites have been exaggerated. While they show a substantial potential in providing transoceanic, high density telephone service, their economical use for television service appears to be limited.” As with so many highly publicized technological advances of the past, the public may be overreacting in expecting large benefits to accrue (as witness the expectation at the close of World War II that each family would soon have its own helicopter). He concluded the article by stating that, “we must, first, decide whether communications is an appropriate area for the expenditure of technical assistance funds and foreign aid loans since underdeveloped countries can be helped in many ways—building roads, hospitals, schools, utilities and a host of others—and a critical question is how best to allocate a given sum of money among them.” Leland L. Johnson, “The Commercial Uses of Communication Satellites: Do Satellites Really Offer a Cheap Alternative to Traditional Methods of Transoceanic Communication?,” *California Management Review* (Spring 1963): 55-66.

The Indian government showed interest early on when the United States was planning a “single global system.” Situated strategically in the middle of Asia, the subcontinent offered a lot of advantages to connect other Afro-Asian regions through communication links. Vikram Sarabhai and V. Pail, Chief Engineer of the Indian Overseas Telecom service discussed the subject early on with NASA officials. NASA expressed willingness to offer Indian participation in future Relay and Comsat projects on the basis of full Government of India (GOI) funding of ground station and other equipment. Sarabhai and Pai discussed the matter further and planned to purchase the necessary ground station equipment costing \$ 700, 000.²⁵⁵

In early 1963, a space science symposium was organized in Ahmadabad. Homi Bhabha along with Vikram Sarabhai and E.V. Chitnis focused attention on satellite communication as an up-coming important field. The main intention was to create manpower, to train people locally who would be able to take over when practical results fructified. Even though the whole concept was still rather hazy, India joined INTELSAT- the international body established to manage a global telecommunications satellite system.²⁵⁶ The efforts Indian officials were putting into this new and emerging field of satellite communication is a visible indication of India’s aspirations for leadership in the Afro-Asian region.

²⁵⁵Memorandum, Embassy of India, Washington D.C., November 20, 1961, RG 59, General Records of the Department of State, Records Relating to Atomic Energy Matters, 1944-63, box 250, NARA II. According to E.V. Chitnis, India could muster only 50,000 Indian rupees for the ground station equipment, seeing the amount insufficient NASA officials asked Chitnis to seek help from United National Development Program (UNDP). The joint effort led to the establishment of Experimental Satellite Communication Earth Station (ESCES) in Ahmedabad. Ashok Maharaj, interview with E.V. Chitnis, January 2009.

²⁵⁶ *Satellite Instructional Television Experiment: Site Winter School, January 16-28, 1976*, (Ahmedabad: Space Applications Centre, Indian Space Research Organization, 1976), pp. 5-16. For an insightful account on the politics of Intelsat see John Krige, Angelina Long and Ashok Maharaj, *Conquest and Collaboration. 50 years of NASA’s International Relations in Space* (forthcoming), Chapter 5, “Technology Transfer in the post-Apollo Program, Part II. Intelsat and Launcher Availability (1971)”

Extensive discussions about using a highly sophisticated broadcast satellite in India appeared in the midst of these developments in the mid 1960s. The proposal gained momentum soon after the Chinese nuclear test on October 16, 1964, at Lop Nur in the Xingiang province. NASA officials suggested this project to the United States State Department as a possible alternative to a similar nuclear test by India. It was hoped that India could appropriate this geosynchronous technology to regain its lost prestige in the community of developing nation-states in the wake of the Chinese test. For the State Department, broadcasting using a geosynchronous satellite figured as one of the strategies to keep India from following China toward a similar test and to channel scarce economic resources toward modernizing a traditional society. For Vikram Sarabhai and others in the Indian space agency this was an opportune moment to actualize the long held vision of technologically leapfrogging the nation using satellites for reaching the rural masses. The geo-political situation created the milieu for NASA to initiate a proposal and test the feasibility of using a geosynchronous satellite for mass communication in a developing country with the additional motive that the project would sell satellites and launches if its feasibility was proven.

The Chinese Nuclear Program and U.S. Response to the Imminent Test

Communist China's nuclear ambitions and its growing popularity among Afro-Asian countries in the 1950s and 60s exerted constant pressure on the United States to seek alternatives that could minimize the Chinese influence in the Asian region. Citing India as the world's largest democracy, U.S. officials hoped to establish that nation as a showcase for American-backed development in the 'third-world' and as an Asian

counterweight to the Communist model in the Peoples Republic of China, PRC.²⁵⁷ In general, there was a pervasive notion that India was a great laboratory that would demonstrate that liberalism and democracy were the way to go, rather than the Chinese model. Chester Bowles, the American Ambassador to India made this argument early on in the 1950s. U.S. officials were cognizant that a nuclear test by the Chinese Communists would alter the status of India, as a democratic leader, in the region. The ensuing paragraphs capture the fears expressed by the United States State Department over a communist state in the Asian region going nuclear and the preventive countermeasures that were contemplated.

Pride and fear have been the dominant factors for nation states to acquire nuclear weapons.²⁵⁸ This is very evident in the Chinese case where Chairman Mao, who once remarked that nuclear weapons were paper tigers, acquired one with Soviet help to deal with perceived external threats.²⁵⁹ During 1961, while analysts at the CIA and the other intelligence agencies tried to determine exactly what progress China had made toward an atomic capability, other arms of the administration began to explore the implications of such an eventuality, and what the U.S. might do to lessen or eliminate its impact. Suggestions from officials in the State Department that the U.S. should assist India to ‘beat Communist China to the punch’ by helping their nuclear weapons program were

²⁵⁷ Dennis Merrill, *Bread and the Ballot: The United States and India's Economic Development, 1947-1963* (Chapell Hill: UNC Press, 1990), p. 5.

²⁵⁸ In his important piece on the causes of nuclear proliferation and nuclear reversal, Scott Sagan advanced three models. The security model viewed the principal cause of both proliferation and nuclear rollback as security concerns, the domestic politics model highlighted the role of domestic group and individual interests, and the norms model emphasized the importance of nuclear weapons in increasing or decreasing the prestige of particular nations, see Scott D. Sagan, “Why Do States Build Nuclear Weapons?: Three Models in Search of a Bomb,” *International Security* 21, no. 3 (Winter 1996-1997): 54-86.

²⁵⁹ Jeffrey T. Richelson, *Spying on the Bomb: American Nuclear Intelligence from Nazi Germany to Iran and North Korea* (New York: W.W. Norton and Company, 2006), pp. 137-138.

immediately vetoed by Secretary of State Dean Rusk who objected that such a step “would start us down a jungle path from which I see no exit.”²⁶⁰

Things began to change in the fall of 1964 when it became apparent that the detonation of a Chinese nuclear device was imminent. Though India was cognizant of the developments on the Chinese side, it came as a shock to the nation when China conducted the test on October 16, 1964. Seeing the situation the United States began to take steps to identify actions that it might undertake jointly with India in the fields of science and technology that could offset the damage of such a detonation to “Indian prestige and self confidence.” These objectives were consonant with paragraph D6 of National Security Action Memorandum (NSAM 355 – Indian Nuclear Weapons Problem), which directs, “A special study should be made of more specific steps, including scientific and technical projects that might be taken to enhance India’s political prestige.”²⁶¹

US authorities reported that a survey of world opinion, soon after the test, showed that Communist China’s nuclear test was unwelcome. The test was strongly condemned in Japan, India, and even the Communist Press of Europe. In Africa, as in other regions, there was concern that China would use its nuclear capacity to browbeat India, Japan and others into submission. There was also fear that Soviet influence in South East Asia would diminish and that Chinese pressures and aggression would become even greater problem.²⁶²

²⁶⁰ William Burr, Jeffrey T. Richelson “Whether to “Strangle the Baby in the Cradle: The United States and the Chinese Nuclear Program, 1960-64,” *International Security* 25, no. 3 (Winter 2000/2001): 54-99.

²⁶¹ Secret memorandum, J. Wallace Joyce to Hare, (undated), Central Foreign Policy files, 1964-1966, RG 59, box 3106, NARA II.

²⁶² Memorandum Carl T. Rowan to Mc George Bundy, October 19, 1964, NSF Subject file, folder, Nuclear Testing China, Vol. 1, box 31, Lyndon Baines Johnson Presidential Library, Austin, TX, (hereafter cited as LBJ Library).

Indian Prime Minister Lal Bahadur Shastri declared the test to be a shock and danger to world peace. Many political parties in India strongly criticized the test and feared that it could cause instability in the region. Two days after the Chinese test, Nath Pai, leader of the Samyukta Socialist Party, told a press conference that India should actively consider acquiring a nuclear deterrent of its own. According to the daily *Indian Express*, Nath Pai urged corrective measures to enable the country to regain its lost prestige among nations.²⁶³ M.R. Masani, the general secretary of the *Swatantra* political party, argued that China's acquisition of the bomb posed not a military threat but rather a psychological and a political one.²⁶⁴

The following are the editorial comments by different national newspapers on the nuclear test by China. The *Statesman* newspaper of New Delhi, commenting on Red China's statement that it would not be the first country to use the nuclear bomb, said 'it is likely to prove cold comfort to the people of India who have had first hand experience of Chinese duplicity and treachery.' *The Hindustan Times* front paged President Johnson's statement that the U.S. was ready to respond to any calls from the non communist countries of Asia for help against threats of aggression, thus offering them assurance in the face of China's emergence as a nuclear power.²⁶⁵

Soon after the test, Indian Ambassador Chester Bowles invited Jerome Wiesner to India to have discussions with the Indian authorities and survey possible areas of scientific and technological cooperation so as to 'restore the international prestige of

²⁶³ "Nath Pai Wants to Produce the Bomb," *Indian Express* (October 19, 1964), cited in George Perkovich, *India's Nuclear Bomb*, p. 66.

²⁶⁴ *Ibid.*

²⁶⁵ These were a collection of clippings found in United States Information Agency "Research and Reference Service, foreign Media reaction to Communist China's Nuclear Device, October 18, 1964, NSF Subject file, folder Nuclear Testing China, Vol. 1, box 31, LBJ Library.

Indian science to its former level and assist in its further increase.’ Wiesner agreed to visit in India in January 1965 along with J. Wallace Joyce, who was the acting Director, International Scientific and Technological affairs, Department of State. Before the visit a list of possible proposals was formulated in consultation with the Atomic Energy Commission (AEC) and NASA. Possible areas of cooperation were narrowed down to: nuclear energy, space and general science.²⁶⁶

Proposal for a Broadcasting Satellite

In line with the cooperative space and space-related projects that were initially planned as prestige projects, a proposal for a satellite broadcasting initiative originated in a letter by NASA administrator James E Webb to U. Alexis Johnson, Deputy Under Secretary for Political Affairs in May 1966. In the letter Webb suggested new avenues for U.S.-Indian collaboration in the practical application of space. The proposal included several other suggestions: 1) A technical experiment in direct broadcasting, 2) a pilot project in the social impact of direct broadcasting, 3) A stimulus to Indian industrial electronics, 4) an attack upon the food and population problems of India. In the memo Webb stated that the U.S. would build and position a synchronous satellite near India in such a way that broadcasts from it could be received over the major part of the Indian subcontinent. He went on to point out that India, for its part, could use its nascent electronics capability now focused at the atomic energy center at Trombay to develop improved television receivers. These could be established in perhaps a thousand rural population centers. Webb was positive about taking the initiative with the Indian

²⁶⁶ Secret memorandum, J. Wallace Joyce to Raymond A. Hare, 10 October 1966, “Science and Technical Cooperation with India,” RG 59, Central Foreign Policy files, 1964-1966, box 3106, NARA II.

government and viewed the satellite broadcast project to offer India some visibility and influence in Asia:

India could learn from the study new technological and management approaches to education and to the uses of informational media to weld together a nation-state. The U.S. would, in turn, learn more about the Indians and their most pressing problems. Should the project come to fruition, then important additional benefits would flow. India would, in its own initiative and with its own resources, begin the accelerated development of modern electronic industry. This bootstrapping operation would materially raise India's technological base and contribute thereby to the development of other, similar industries. Some Indian energy might also be diverted from concern with nuclear weapons development, the more so perhaps as the success of the experiment contributed to India's prestige in Asia. The posture of the U.S. would also be improved through a generous demonstration of its willingness to share the benefit of advanced space technology with underdeveloped nations. Even should it prove infeasible in the end, both we and the Indians could not fail to have profited by the intimacy of our cooperation in a joint technological venture.²⁶⁷

Indian Requests for a 'Spectacular'

After the Chinese test, Vikram Sarabhai and Homi Bhabha made periodic visits to the United States to negotiate cooperative projects designed to boost India's scientific capability. In select meetings held in Washington D.C. Bhabha expressed the dilemma India faced regarding what to do to counteract the "noise" (a term used by Bhabha) of Communist China's nuclear explosion. He explained that India needed to make some dramatic peaceful achievement to offset the attraction gained by China among Africans and Asians. He reexamined India's accomplishments in the area of nuclear energy and contrasted them with those of China. India could quite easily have achieved China's

²⁶⁷ Confidential letter, James E Webb to U. Alexis Johnson, Deputy Under Secretary for Political Affairs, Department of State, May 19, 1966, RG 59, folder SP- Space & Astronautics 1/1/64, box 3140, NARA II.

capability; however Bhabha noted that the Chinese were greatly indebted to the U.S.S.R. for help on their weapon program. Bhabha explained that if India went all out, it could produce a nuclear device in eighteen months; with a U.S. blueprint it could do the job in six months.²⁶⁸ Bhabha expressed the view that “if India was to maintain its prestige relative to the Chinese in the field of science and technology two things should be done: (1) ways must be found for it to demonstrate to other Asian and African countries India’s scientific achievements, (2) a greater awareness of Chinese indebtedness to the Soviet Union for its nuclear achievements must be created.”²⁶⁹

Bhabha also met with NASA Administrator James E. Webb, Deputy Administrator Hugh Dryden, and with Arnold Frutkin. During the meeting Bhabha swiftly moved away from the option of a Peaceful Nuclear Explosion (PNE) to discussing the possibility of India developing a satellite orbiting capability. Bhabha stated that if India undertook such a project, it would wish to launch from India and do the largest part of the job itself. Hearing this from Bhabha, NASA presented estimates of cost, technology and time requirements, all of which suggested this was not a project well adapted to achieve Indian objectives. NASA also pointed out that by the time India orbited a satellite, several other nations would likely have progressed so far in this field that India’s accomplishment would appear relatively insignificant. Webb's line of thought differed with that of Bhabha; he said that a major effort should be made to select projects which would have a meaningful impact on Indian technology and industrial growth, not spectacles which would drain resources to no useful social effect.

²⁶⁸ Secret memorandum, J. Wallace Joyce to Hare, (undated) RG 59, Central Foreign Policy files, 1964-1966, box 3106, NARA II.

²⁶⁹ Ibid.

During his meeting with Glenn Seaborg, Chairman of the US Atomic Energy Commission (AEC) he alluded to other glamorous projects like the development of a nuclear maritime propulsion system. The AEC agreed this might be good prestige project which was worth further study. Other ideas put forward concerned plutonium and thorium recycling, and Indian cooperation with the U.S. in fast-breeder research. Bhabha raised the issue of plowshare, the use of nuclear explosions for peaceful construction purposes, and expressed interest in U.S. devices that could perform such tasks as deepening the channel between Ceylon and India and strengthening the Hoogly river. During technical discussion both at NASA and the AEC Bhabha maintained that in order to offset the lead gained by Communist China through the detonation of a nuclear device Indians must effectively demonstrate their scientific accomplishments in peaceful uses. Bhabha saw this as long term task which Indians must take on largely themselves, with a minimum of visible external assistance. At various time during discussions he restated India's determination to use nuclear energy for peaceful purposes.

Sarabhai who headed the Indian Committee on Space Research (INCOSPAR) also made a visit to the United States seeking scientific and technological aid in the area of space. Sarabhai viewed science and technology only as tools for socio-economic development and not for strategic needs. In his lectures that he gave at select institutions in America he made remarks regarding his personal philosophical approach to the economic development of India. Essentially, his approach derived from the assumption that if the gap between rich nations and poor nations like India was ever to be narrowed, the poor nations would have to try to leap frog directly to applications of advanced scientific techniques. His approach to research and technological development and

industrial collaboration emphasized self reliance and self sufficiency: “we do not wish to acquire *black boxes* from abroad but to grow a national capability.”²⁷⁰ He saw high technologies like nuclear power and space as crucial to modernity. Sarabhai added that there was some pressure within India to build a nuclear bomb, and to deflect this pressure India needed to do something else to demonstrate an advanced scientific capability.²⁷¹

James Webb’s proposal of educational television complemented the initiatives taken by Sarabhai and his team to harness the new medium for reaching the untold masses. In the society for International Development at Delhi in 1968 he said “for the rapid and sustained growth of developing countries, the urgent need to disseminate information to the masses is obvious.” When direct broadcasting using satellites was visualized as a possibility Sarabhai began to imagine a national satellite system to provide a better way of life to the inhabitants of more than half a million Indian villages. He wanted to harness this cost-effective technology so as to bypass the expensive conventional methods of using towers and microwaves to beam programs in the vast sub-continent. He hoped that, thanks to the research and development activities of the space program, television would be available to 80 percent of India's population within ten years. This project was of special significance because by providing entertainment and instruction of high quality, it would be possible to bring about a qualitative improvement in the richness of rural life.²⁷²

²⁷⁰ Vikram Sarabhai, *Science Policy and National Development* (New Delhi: Macmillan, 1974), p. Xiv.

²⁷¹ Memorandum, Department of State to Secretary of State, October 17, 1966, RG 59, Central Foreign Policy File 1964-66, box 3106, NARA II.

²⁷² Arnold W. Frutkin, “The India-U.S. Satellite Broadcasting Experiment,” record no. 14641, folder SITE, NASA Historical Reference Collection, Washington D.C. See also, Vikram Sarabhai, *Science Policy and National Development*, p. Xii.

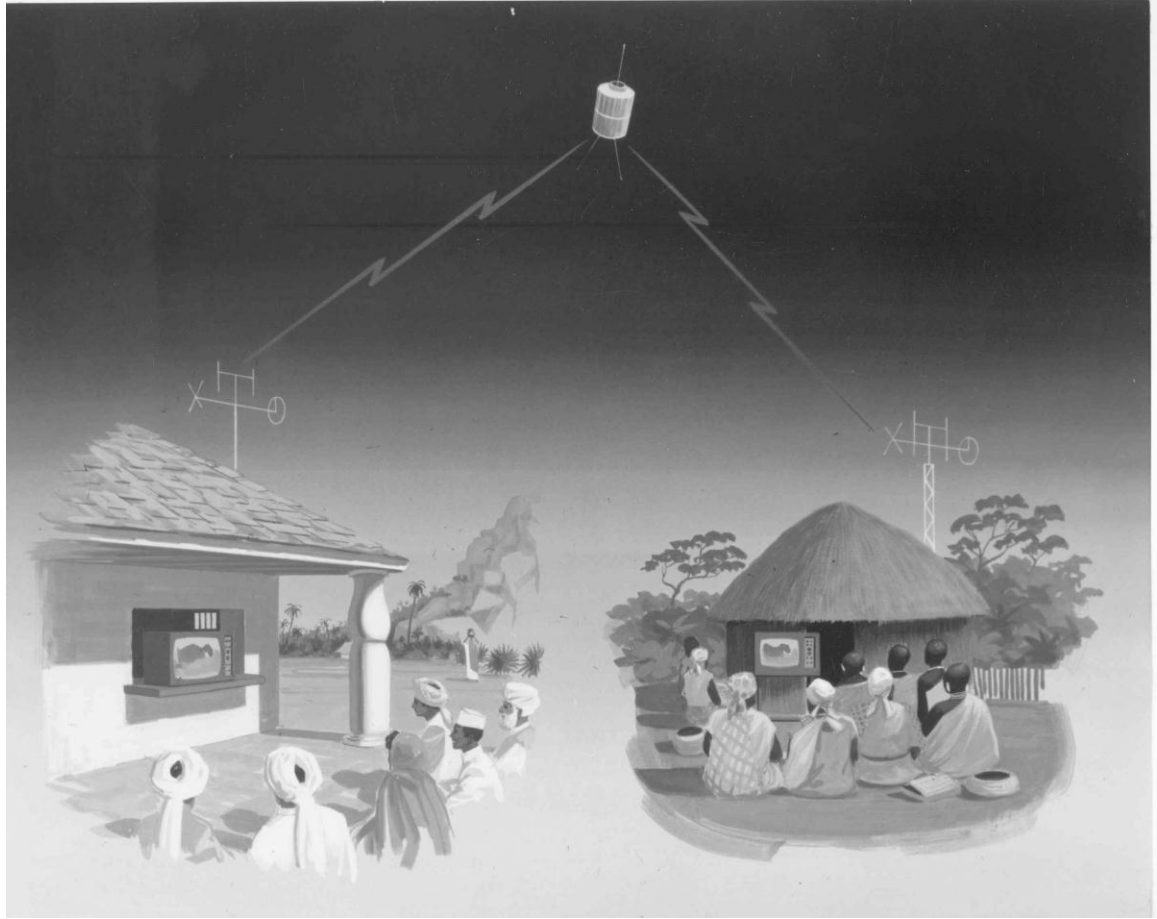


Figure 18: Artist conception of direct broadcast instructional television.

Source: NASA

The U.S. administration viewed direct-broadcast television using advanced satellites as a step toward enhancing India's scientific and technological base. It offered the State Department twin benefits: a benign technological tool to offset Communist China's influence, and a technology that would help to bring literacy and development to the rural population. This was perfectly in line with what the communication scholars and media experts were promoting in the late 1950s, the idea that television and other media of mass communication would help toward national development. Influential works by Daniel Lerner and Wilbur Schramm who based their theories of development and media

efficacy on Walt Rostow's influential *The Stages of Economic Growth: A Non Communist Manifesto*, became key texts for government leaders to promote mass media in their respective countries.²⁷³ In the book Rostow stressed that the economic and technological development achieved by the Western nations were the result of increased media use. If the developing countries could follow the path of modernization initiated by the West, they would leapfrog centuries of inaction and underdevelopment and catch up with the modernized West.²⁷⁴ Walt Rostow who later became the national security adviser to Lyndon Johnson, was himself interested in putting "television sets in the thatch huts of the world to defeat both tradition and communism with the spectacle of consumption."²⁷⁵

The political value of communication satellites was also emphasized by Arthur C. Clark:

Living as I do in the Far East, I am constantly reminded of the struggle between the Western World and the USSR for the uncommitted millions of Asia. The printed word plays only a small part in this battle for the minds of the largely illiterate population and even radio is limited in range and impact. But when line of sight TV transmission becomes possible through satellites directly overhead, the propaganda effect may be decisive...the impact upon the peoples of Asia and Africa may be overwhelming. It may well determine whether Russian or English is the main language of the future. The TV satellite is mightier than the ICBM;

²⁷³ W.W. Rostow, *Stages of Economic Growth: A Non-Communist Manifesto* (Cambridge: Cambridge University Press, 1960). For a closer critical analysis of Rostow's work and on modernization see, David C. Engerman, Nils Gilman, Mark H. Haefele and Michael E. Latham, *Staging Growth: Modernization, Development and the Global Cold War* (Amherst: University of Massachusetts Press, 2003). Michael E. Latham, *Modernization as Ideology: American Social Science and 'Nation Building' in the Kennedy Era* (Chapel Hill: University of North Carolina Press: 2000). Nils Gilman, *Mandarins of the Future. Modernization Theory in Cold War America* (Baltimore: Johns Hopkins University Press, 2007).

²⁷⁴ John V Vilanilam, *Mass Communication in India: A Sociological Perspective* (New Delhi: Sage Publications, 2005), p. 154.

²⁷⁵ Nick Cullather, "Miracles of Modernization: The Green Revolution and the Apotheosis of Technology," *Diplomatic History* 28, no.2 (April 2004): 227-254.

this is the fact which I would most earnestly bring to the attention of your committee.²⁷⁶

India was particularly appropriate for a satellite experiment in the direct broadcasting of TV. First, there was no existing TV distribution network which could be utilized by conventional means. The population was distributed relatively homogeneously throughout the subcontinent rather than concentrated in a few large cities easily reached by conventional TV, and there was a high level of Indian government support for this kind of experiment. This contrasted with the United States where an established conventional TV system already covered most of the country. It also contrasted with other developing countries, for instance Brazil. There, a substantial portion of the population was concentrated in coastal cities, all of which already possessed TV networks, while only the scattered inland population lacked TV. So, India stood apart as an ideal laboratory for testing the technology. Wallace Joyce, in the International Scientific and Technological Affairs of the State Department, particularly liked Webb's proposed use of the American television broadcast satellite to service community receivers built in India. It had the potential for India to exert "regional leadership" in space-related educational TV for development purposes in the surrounding Asian and other modernizing regions.²⁷⁷

For Frutkin, the instructional television project was a constructive step forward in cooperation between one of the world's superpowers and a progressive, neutral, developing nation. "For other developing countries, it should serve on a non cost basis to

²⁷⁶ *Next Ten Years in Space, 1959-1969*, Staff Report of the Select Committee on Astronautics and Space Exploration, 85th Congress, 2nd session, p. 32.

²⁷⁷ Memorandum, Wallace Joyce to Hare, October 10, 1966, "Scientific and Technical Cooperation with India, RG 59, Central Foreign Policy Files 1964-66, folder SCI- Science and Technology, box 3108, NARA II.

test the values, the feasibility, and the requirements of a multi-purpose tool which could be critical to accelerating their progress in an increasingly technological world.”²⁷⁸ There is “some measure of generalization, hyperbole, and technological misconception” when it came to direct broadcasting of television, remarked Frutkin. In order to realistically consider the problems and technological hurdles associated with direct broadcasting he sought an “actual experience with the medium.” The experiment represented a “rarely grasped opportunity to use modern technology so as to leapfrog historical development stages.”²⁷⁹

The Indian space experts too were interested in exploring the potentialities of TV as a means of mass communication in a developing country. NASA provided an opportunity for this kind of experiment. In 1967, only Delhi, the capital city of India had television transmission services. The Indian broadcast planners organized under the Ministry of Information and Public Broadcasting (MIPB) wanted to extend the television services by first focusing on the cities and gradually extending it to rural villages through transmitters. Seeing the cities to be already “information rich” through various other media, Vikram Sarabhai, in contrast to the broadcast agency – which blamed the space agency for unnecessarily encroaching on their domain -- wanted the villages to receive the high technology first. In June 1967 Sarabhai sent a team to NASA to study the prospects of using a satellite over a conventional transmission links. After looking at various options, the visitors focused in on a “hybrid system for rebroadcast stations for

²⁷⁸ United States. Congress. House. Foreign Affairs, *Foreign Policy Implications of Satellite Communications, Hearings Before the Subcommittee on National Security Policy and Scientific Developments...* 91-2, April 23, 28, and 30 (U.S. Govt. Print. Off, 1970).

²⁷⁹ Arnold Frutkin, The India-U.S. Satellite Broadcasting Experiment, folder SITE, NASA Historical Reference Collection, Washington D.C.

high population areas, and a satellite for interconnection and transmission to low-population density areas.” The interaction between NASA, Indian actors and the business corporations in America planted the seed for the Indian National Satellite (INSAT) that was developed and launched during the early eighties.²⁸⁰

To test the efficiency of such a massive system for the entire Indian population officials at NASA and the State Department conceptualized a limited one year SITE project using the ATS -6 satellite. The SITE project was not without domestic resistance, however. Different arms of the Indian government raised objections. The Finance Ministry viewed the satellite route to be expensive and questioned why the potential of radio has not been harnessed for reaching the rural masses. Rural administrators stated that satellite television would “raise villager aspirations” which they not be able to meet. The ultra high frequency used by the geosynchronous satellite would interfere in their normal operations, so the Defense Department was against it. Economists questioned the financial investment in satellite TV when primary schools and other development projects needed the resources. To reach a consensus among different agencies Sarabhai set up an ad hoc National Satellite Telecommunications Committee (NASCOM) in 1968 for the approval of SITE. After much deliberation the Cabinet approved the SITE project in February 1969.²⁸¹ To this it should be also added that “Sarabhai [...] put personal reputation on the line in persuading Mrs. Gandhi, to use the satellite approach”²⁸²

An agreement was signed between NASA and ISRO in the Fall of 1969 wherein NASA agreed to pay for the construction of the satellite, its launch, and its operation for

²⁸⁰ Bella Mody, “Contextual Analysis of the Adoption of a Ccommunications Technology: The Case of Satellites in India,” *Telematics and Informatics* 4, no. 2 (1987):151-158.

²⁸¹ Ibid.

²⁸² Memorandum, David T. Schneider, to Van Hollen, February 5, 1970, “Status of the Educational Satellite Program in India, RG 59, Records Relating to India 1966-1975, box 25, NARA II.

one year. NASA provided the space segment while ISRO took charge of the ground segment and programs. NASA helped ISRO to a certain extent by offering training facilities to its engineers at different NASA facilities and by helping in the procurement of critical components when these were urgently required at short notice. Numerous ISRO-NASA meetings held in India and America helped in sorting out interface problems and in acquainting each other with the progress of the SITE project. While preparing for this project joint studies were also done by ISRO engineers with NASA and private corporations like Hughes Aircraft, and General Electric for configuring the systems for the Indian National Satellite (INSAT). In 1970, ISRO engineers undertook a study at Lincoln Labs at MIT for spacecraft studies of INSAT. Sarabhai planned INSAT as a follow on after the SITE experiment.²⁸³

Krishi Darshan (Agriculture TV Program)

In order to plan the for the year long SITE project, the INCOSPAR with the help of the Indian Agricultural Research Institute, All India Radio, and the Delhi Administration undertook an experimental pilot project to telecast biweekly twenty minute agricultural programs called, Krishi Darshan, around Delhi (it was commonly called the *Delhi Project*).

²⁸³ The Ford Foundation paid \$65,000 to the Government of India to facilitate scientists at DAE and ISRO under the leadership of Sarabahi to conduct studies at MIT -- Lincoln labs, on the design configuration of the INSAT, Confidential memorandum, Kenneth Bernard Keating, American Embassy, New Delhi, to Secretary of State, Washington D.C., July 21, 1970, "GOI Satellite ITV Program," RG 59, Subject Numeric Files, 1970-73, box 2962, NARAIL.

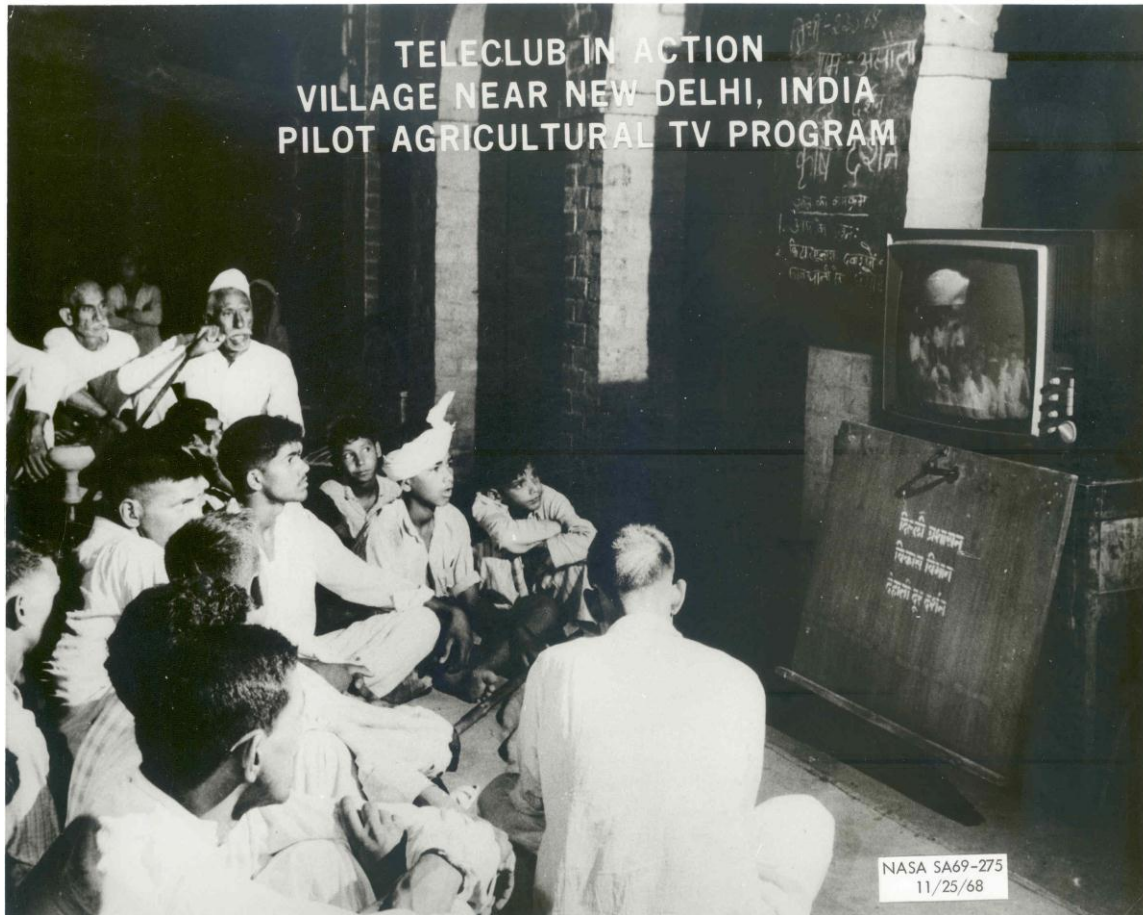


Figure 19: Krishi Darshan

Source: NASA

The project was undertaken to understand the social and organizational and managerial problems before TV could be used on a wide scale as a lever for development.²⁸⁴ The project was conducted literally as an experiment with control groups, and experimental group and statistical analysis was done on the effectiveness of using television programs to impart rural education. For evaluation purposes the INCOSPAR roped in the experts from Department of Adult Education of the National Center for Educational Research and Training (NCERT). A similar experiment using

²⁸⁴ For a detailed cost benefit analysis of the paper see, Prasad L. Vepa, "Opportunities Available to Developing Nations Through the Use of Communication Satellites – the Delhi Project" *Space Research in India* (Ahmedabad: INCOSPAR, Physical Research Laboratory).

radio was undertaken in the early sixties but owing to the proliferation of transistors an effective method of imparting literacy through a community mode did not materialize. A visual medium was felt more important to impart education. In an entertaining way two agriculturalists wearing traditional clothes shared the importance of weedicide, pesticide, use of fertilizer, high yielding varieties of wheat, with the village audience. To capture the audience, the twenty minute programs were interlaced with folk music and dance. It was not lecture driven. “Clarity, credibility and practicability” was the main goal of these programs. The project was started on, 26th January 1967 (The Indian Republic Day). The transmitter in Delhi had the range of 23 miles. Eighty villages were chosen based on electrification and the television was imported by a commercial dealer with an one year guarantee. “Teleclubs” or discussion groups were coordinated by the planners of this project. Television sets were placed in rural villages around Delhi to test “software development, receiver maintenance, and audience information utilization.”²⁸⁵ Arnold Frutkin and Richard Barnes witnessed the programs one evening in a village outside New Delhi. And they saw how programs were well received by the audience.²⁸⁶

SITE the Hardware

How to reach the backbone of Indian society -- 568,000 linguistically and culturally heterogeneous Indian villages, with educational television? This was the central question that plagued the planners since the early 1960s long before the signing of the MoU between India and NASA in 1969. Studies on various technological combinations were done by RAND Corporation, academic institutions, NASA, industrial organizations, the Indian Department of Atomic Energy, and also at a scientific meeting

²⁸⁵ Mody, “Contextual Analysis of the Adoption of a Communications Technology,” pp. 151-158

²⁸⁶ Arnold W. Frutkin, “The India-U.S. Satellite Broadcasting Experiment,” folder SITE, NASA Historical Reference Collection, Washington D.C.

organized by the United Nations.²⁸⁷ In the end, to suit the Indian requirements, the space officials in India along with international experts selectively appropriated a unique “hybrid system” for executing SITE. This system utilized a synchronous satellite providing the broad-band communication link for re-diffusion from ground stations in areas where the density of sets was large, and direct broadcast receivers where the density of sets was low.²⁸⁸

²⁸⁷ These studies portrayed different scenarios and technological methods. The first joint study group between NASA and DAE was held in 1968 between January 22-30, at PRL in Ahmedabad with Arnold Frutkin and Vikram Sarabhai. Sarabhai elaborated his choice of the Hybrid system – a combination of direct broadcast and satellite redistribution system, as the most suitable in India for reaching the villages. The meeting brought together a variety of experts from NASA and India to discuss the orchestration of satellite television. From the American side the co-chairman was Leonard Jaffee, Director of Space Applications Programs, NASA, and on the Indian side it was B.S. Rao, Central Electronics Engineering Research Institute, Birla Institute of Technology, Pilani. Other members were A.M. Greg Andrus, Chief of Communications program, NASA; M.S. Nagarajan, Overseas Communication Service, Government of India, Bombay. The chief consultants for the program were E.V. Chitnis, M.S. Swaminathan, Director, Indian Agricultural Research Institute, New Delhi; Samuel Paul, Professor of Economics, Indian Institute of Management, Ahmedabad; V. Kurien, General Manager, Kaira District Cooperative Milk Producers' Union Ltd, Anand; Ashok Parthasarathy, Senior Scientific Officer, Department of Family Planning, Government of India; Frank Wilder, Consultant in Mass Communications, Department of Family Planning, Government of India; T.S. Mehta, National Council of Educational Research and Training, New Delhi; Romesh Chander, Director, Staff Training School, All India Radio, New Delhi; B.Y. Nerurkar, Deputy Chief Engineer, All India Radio, New Delhi, “Composition of the Joint Study Group,” record no. 14641, folder SITE, International Cooperation and Foreign Countries, NASA Historical Reference Collection, Washington D.C. Though this meeting was the first joint effort between NASA and India, there were other significant studies carried out at different institutions since the mid 1960s, see, Wilbur Schramm and Lyle M. Nelson. *Communication Satellites for Education and Development-the Case of India*. Stanford, Calif: Stanford Research Institute, 1968; *Advanced System for Communications and Education in National Development (ASCEND)*, School of Engineering, Stanford University, 1967; *Satellite Television Relay for India's Development and Education (STRIDE)* College of Engineering, West Virginia University, May 1967; Penna Lakshmikanth Rao, “Community Broadcast Satellites (Application Technology Satellites - F and G) for Instructional Television in the Developing Countries,” Program of Policy Studies in Science and Technology, The George Washington University, February 1, 1968; Penna Lakshmikanth Rao, “Broadcast Satellite System for India: A Policy Study of Socio-economic and Political Benefits and Problem Areas,” Program of Policy Studies in Science and Technology, The George Washington University, November 16, 1967; Laurence C. Rosenberg, “On Costs and Benefits of a National Television System for India, *Indian Economic Journal*, No. 1 (July – September 1966); Hughes Aircraft Company, Space Systems Division, Educational Television Satellite System for India, SSD60240B (June 1966); Harold A. Rosen, “Satellite System for Educational Television,” United Nations Conference on the Exploration and Peaceful Uses of Outer Space, A/Conf. 34/I.5, 20 June 1968; B.S. Rao, Prasad L. Vpa, M.S. Nagarajan, H. Sitaram and B.Y. Nerurkar, “Satellite Television: A System Proposal for India,” United Nations Conference on the Exploration and Peaceful Uses of Outer Space, A/Conf. 34/I.1, 24 June 1968.

²⁸⁸ V.A. Sarabhai, E.V. Chitnis, B.S. Rao, P.P. Kale and K.S. Karnik, “INSAT—A National Satellite For Television and Telecommunication,” *Electronics*, Proceedings of the National Conference on Electronics Organized by the Electronics Committee, Government of India, Bombay, 24-28 March 1970 (Electronics Commission, Government of India): 487-493.



Figure 20: ATS-6 support network.

Source: NASA

The operation and execution of the experiment was dependent on a network of complex technological systems. Occupying the central node in the whole network was the ATS-6. It functioned as a relay station for receiving and sending signals originating in India; in other words it acted as a channel of communication between the transmitter and the receiver. The re-transmitted signals from ATS-6 were received on the ground by earth stations and Direct Reception Systems (DRS). The United States provided the satellite while the full responsibility for the ground segment – earth stations, DRS and television programs (software) -- was done by India with domestic and international expertise.

ATS-6

After the success of the Synchronous Communication (Syncom) series of satellites beginning in 1963, the Early Bird satellite (Intelsat I) was launched in 1965 and, for the first time, it proved that communication from a geosynchronous orbit was indeed possible. What followed was a series of satellite feasibility demonstrations using NASA's ATS satellites (1, 3 and 5). They were designed to carry out technological, meteorological, scientific and communications research. The last of the series was ATS 6. It was designed and manufactured by the Fairchild Corporation for NASA. The spacecraft carried fifteen scientific experiments in the field of communication, meteorology and spacecraft stabilization.²⁸⁹ Launched by a Titan III C rocket on 30 May, 1974, the satellite was placed in a geostationary orbit to beam educational, medical and cultural programs to different regions across globe.

²⁸⁹ For more on the ATS satellite see Arnold Frutkin, "Direct/Community Broadcast Projects using Space Satellite," *Journal of Space Law* 3, no. 1 & 2 (January 1975): 17-24. K. Narayanan, "Special Features of ATS-6 Satellite" in *SITE Winter School*, pp. 43-52.

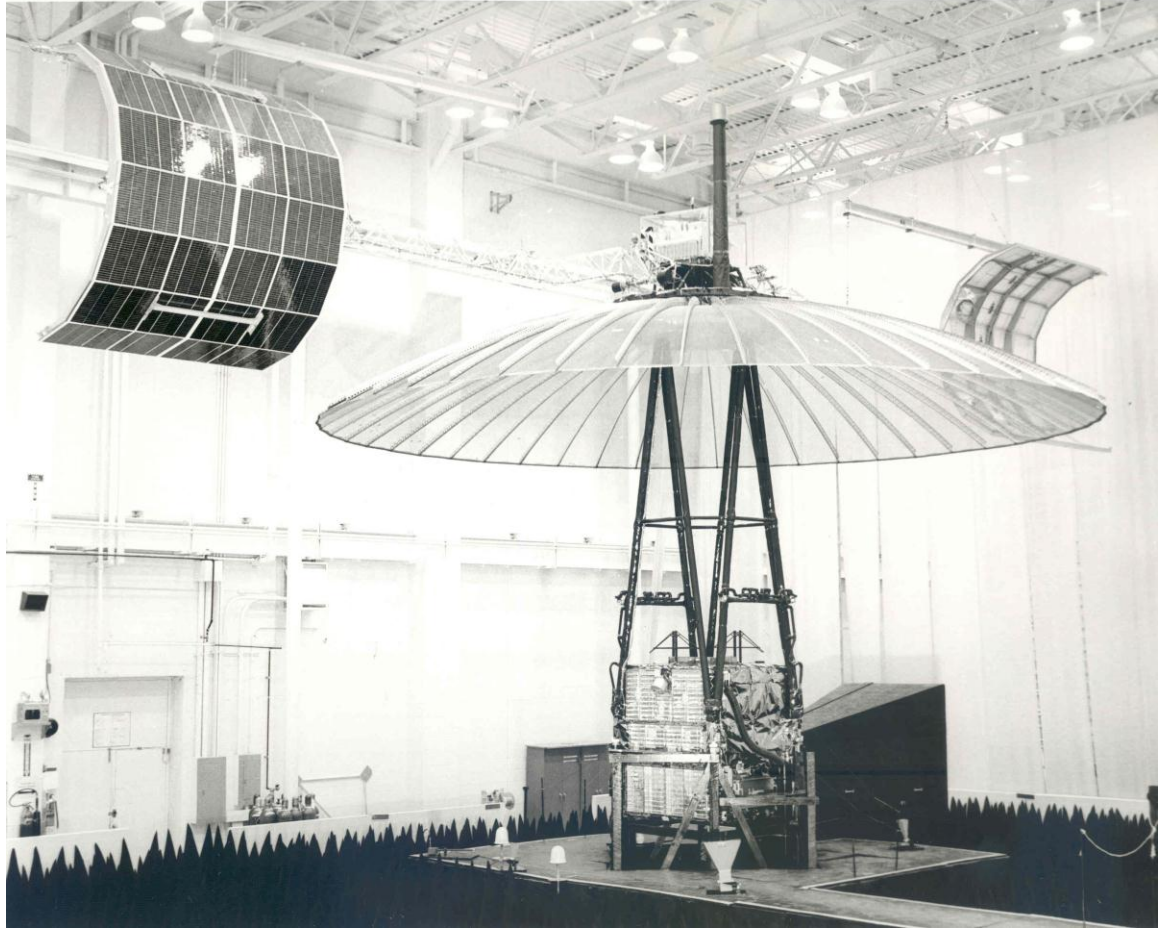


Figure 21: ATS 6 Satellite before launch.

Source: NASA

The sophistication comes from the satellites' ability to radiate enough power through its thirty foot diameter antenna, with a pointing accuracy of $1/10^{\text{th}}$ of a degree of arc in all three axes (with an advanced attitude control system), to rebroadcast received signals/programs directly to small ground stations or directly to augmented television sets over a large area – a foot print of 1000 miles long and 300 miles wide. In general it served as a powerful rebroadcasting station, akin to those found terrestrially, in space. The two high power signal transmitters were powered by onboard semi-cylindrical solar panels. ATS- 6 was designed in such a way that it could be moved along the equator

using its onboard thrusters to conduct space based experiments in any region of the globe. The stability factor is important for conducting various technological and scientific experiments. The SITE was made possible when all of these objectives were achieved.²⁹⁰

Before moving the satellite to broadcast educational programs in India, the satellite was used to perform a variety of health and education television experiments in the Appalachian area, the Rocky Mountain Region and Northwest U.S. including Alaska.²⁹¹ After completion of the SITE experiment in India, the satellite demonstrated practical applications to 27 different developing countries under a project named AIDSAT. It was a demonstration project jointly orchestrated by the U.S. Agency for International Development (AID) of the U.S. State Department and NASA. Finally, before the satellite was de-orbited in 1979, the International Christian Broadcasters, Clearwater, Florida used the ATS 6 to telecast instructional programs to Puerto Rico and the Virgin Islands.²⁹²

Earth Stations

The earth stations and the DRS formed the ground segment of the network. The earth stations help in transmitting signals to the satellite and the satellite receives these signals, amplifies them and transmits them back to earth where they are received by

²⁹⁰ The 30 ft deployable antenna helps to concentrate the radio frequency power into a narrow beam. At 860 MHz, the frequency at which SITE operated, this beam is only 2.8 degrees wide and illuminates a circle of about 1800 km diameter. Since the beam was very narrow it had to be directed to a desired point. Even a small error in pointing will mean that a large area intended to be covered will not receive the signal power. Hence the second objective of 0.1 degree pointing capability.

²⁹¹ Using ATS-6 for the American region was not originally intended. The plan was implemented when the committee voiced protest of why an advanced technology should not have practical benefits for the American region, see U.S., Congress, House Committee on Foreign Affairs, Subcommittee on National Security Policy and Scientific Developments, *Hearings, Foreign Policy implications of Satellite Communications*, 91st Cong., 1st sess., 1969.

²⁹² For a brief description of each project see Robert O. Wales, *ATS-6 Final Engineering Performance Report*. Washington, D.C: National Aeronautics and Space Administration, Scientific and Technical Information Branch, 1981. Timothy Stoneman, "Project Look Up: NASA and Satellite Evangelization," Society for the History of Technology, Annual Meeting, 2009, Pittsburgh, USA.

custom made television sets that are suitably tuned. Four earth stations, located in Ahmadabad, Delhi, Amristar and Nagpur were utilized for the SITE project.

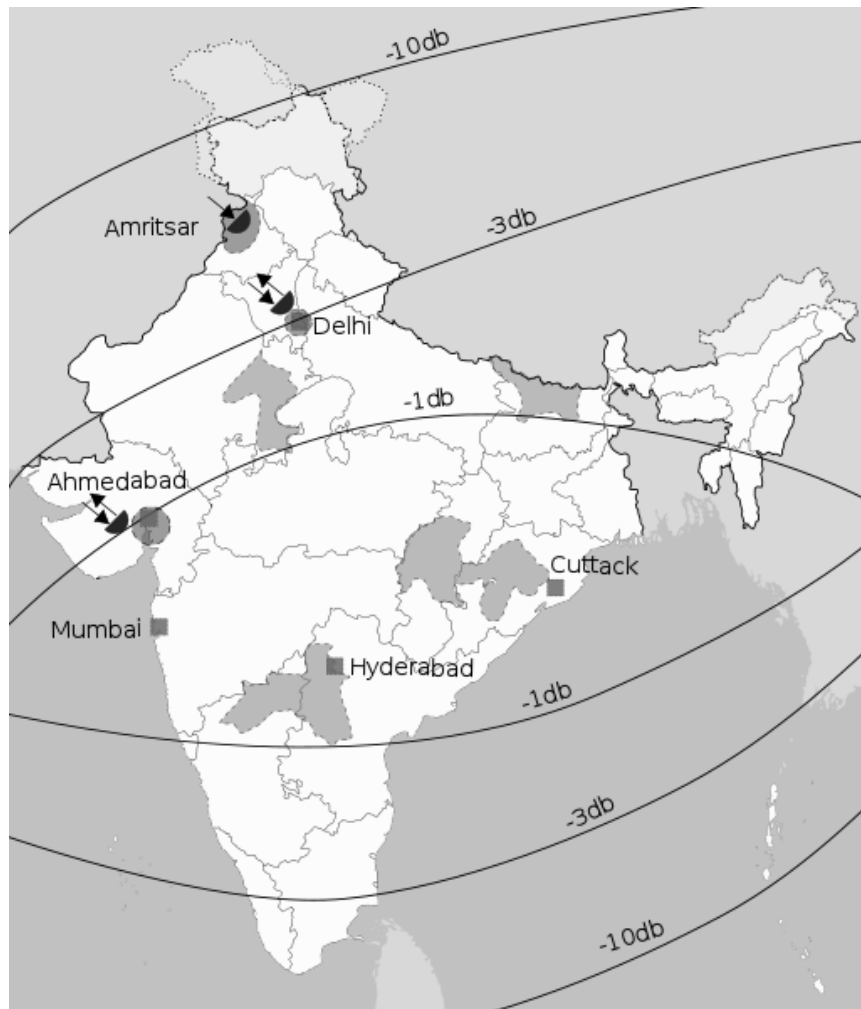


Figure 22: Earth Stations for SITE

Source: UNESCO

The Experimental Satellite Communication Earth Station (ESCES) located at Space Applications Center in Ahmedabad, was the central earth station that transmitted the bulk of the SITE programs to be delivered via ATS-6 to the village clusters. ESCES was established in 1967 with partial help from United Nations Developmental Program

(UNDP) funds.²⁹³ For the SITE program ESCES was upgraded to meet the technical requirements for transmitting the signals to ATS-6.

The earth station at Delhi, a much simpler one compared to ESCES, was also upgraded for SITE experimentation. A 10 meter parabolic antenna at Delhi was used for telecasting national programs and also served as a backup facility if the central station in Ahmadabad were to face any technical glitches. The availability of studio facilities, created by All India Radio, for news broadcast and other national programs (Independence day program, Republic Day Parade, children's program) was also one of the rationales for having another earth station in Delhi. The third earth station was located in central India in Nagpur. It housed the 'monopulse beacon' instrument. The ATS-6 satellite had the capability of 'homing in' to a beacon station located to keep the satellite accurately oriented if its internal pointing systems failed. This was one of the important back up modes to ensure the ongoing functionality of the ATS-6 spacecraft. The required hardware for the Nagpur station, 2-watt S band transmitters, antenna and other subsystems, was made in India because of bureaucratic problems in importing it. All the earth stations were pre tested by International Telecommunication Union (ITU) experts before the broadcasting began.

²⁹³ UNDP funds were provided under project IND-44, see O.P. Rustogi, "Contribution of Foreign and Indian Agencies for SITE – I," in *Satellite Instructional Television Experiment: Site Winter School, January 16-28, 1976*, (Ahmedabad: Space Applications Centre, Indian Space Research Organization, 1976).

Direct Reception Systems (DRS)

Television sets modified to receive signals directly from the satellite were designated as Direct Reception Systems (DRS). They completed the vast network that was put in place for SITE. The system had three main units: 3 meter diameter parabolic chicken mesh antenna to receive the signals transmitted by the satellite, the front end converter (FEC) to transform the signals into a form compatible with a normal television receiver, and a modified television receiver. During the signing of the memorandum of understanding for SITE in 1969, only ten percent of the Indian villages had electric power, and TV manufacturing in India was still in the formative stages.²⁹⁴ Massive efforts went toward electrifying the villages and the mass production of DRS.

The development of the DRS exclusively for SITE was started in 1971 at the Electronics Systems Division of the Space Applications Center in Ahmadabad with collaboration from NASA. The prototype of the frontend converter and Chicken mesh antenna was then transferred to Electronics Corporation of India (ECIL) located in the city of Hyderabad in the State of Andhra Pradesh. To facilitate transfer of ‘know-how’ and to expedite production, some ISRO engineers from the Space Application Center who had developed these units were posted to ECIL.²⁹⁵ The television monitor itself was basically a commercial model slightly modified for community viewing and rural use. “Seven hundred of the 2400 sets were ‘ruggedized’ by using higher quality components, as a part of an ‘experiment-within-an-experiment’ to investigate the tradeoffs between

²⁹⁴ JK Electronics, located in the city of Kanpur in Northern India was the only firm that had some rudimentary set up for manufacturing television sets.

²⁹⁵ Romesh Chander and Kiran Karnik, *Planning for Satellite Broadcasting: The Indian Instructional Television Experiment* (UNESCO Press, 1976), p. 20.

initial cost and maintenance cost.”²⁹⁶ From the beginning, the Indian government took the position that it wanted to assume the maximum amount of control and responsibility for the design, production and operation of the system. One reason that 860 mhz (ultra high frequency) was selected for transmission from the satellite was that the electronics required for its reception could be designed and produced in India.²⁹⁷ Every unit of the DRS – FEC, antennas and modified television sets was tested in India and the United States during the course of its development.²⁹⁸ A final testing of the DRS was conducted with the ATS-6 in orbit in 1974 by Pramod Kale and his team at SAC Ahmedabad.²⁹⁹

²⁹⁶ Clifford Block, et.al., “A Case Study of India’s Satellite Instructional Television Project,” *AID Report*, (January 1977), p. 5.

²⁹⁷ Ashok Maharaj, interview with Pramod Kale, January 2009.

²⁹⁸ P.P. Kale, Satellite Instructional Television Experiment in Retrospect, ISRO Report R13713, SAC Library, Ahmedabad, (Undated).

²⁹⁹ Broadcasting UHF signals in USA was against the law, so Kale and his team tested the sets at 2:30 am in order not to raise any public complaint because of interference. While testing the engineers observed that the signals received were 10 times lower, that is 20 db down. Kale detected a polarization problem and quickly found a technical solution to minimize the polarization effect. Once when the problem was identified and fixed he directly called ECIL, which was manufacturing the television system, to reconfigure the sets. Additional testing was also done to the TV cabinet by putting it in a vibration table in GSFC. Based on further observations on the vibration table, modifications were made on the wooden cabinet, and installed with replaceable fuses (this is what “ruggedized” actually meant). Ashok Maharaj, Interview with Pramod Kale.



BROADCAST SATELLITE BRINGS EDUCATION TO INDIAN VILLAGE



NASA HQ AD76-1709 (2)
1-8-76

Figure 23: Left – Chicken mesh antenna. Right – People watching SITE program.

Source: NASA



Figure 24: Complete DRS system.
Chicken mesh antenna and television for receiving the television signals directly from the ATS-6 satellite. Source: *The Hindu – Photo Library*.³⁰⁰

The fully assembled Direct Reception Systems were deployed in selected villages and the districts of six states viz. Andhra Pradesh, Bihar, Karnataka, Madhya Pradesh, Orissa and Rajasthan. The villages were selected according to the criteria laid down by the Planning Commission of India. The criteria included availability of electricity, public buildings,

³⁰⁰ <http://www.hinduonnet.com/fline/fl1809/18090100.htm> (accessed on 16 February, 2009).

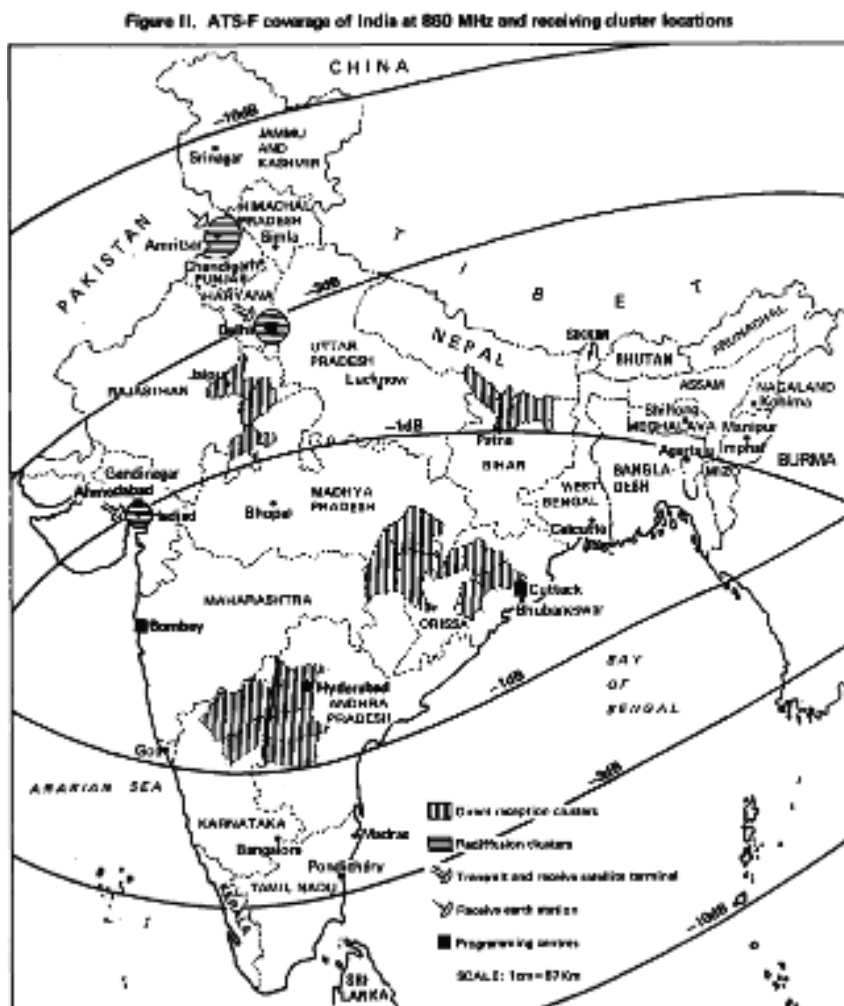


Fig. 25: ATS-6 coverage in India

Source: UNESCO*

low population etc. To carry out an organized effort of deployment, operation and maintenance of these television sets, maintenance sub-centers and a central cluster headquarters were established in each State. These cluster headquarters acted as nodes for the distribution and maintenance of the community reception system. First to be installed in the villages was the antenna. TV sets were installed later on and kept ready for the experiment.

In July 1975, while it was being shifted eastward along the equator for the SITE mission, the ATS-6 tracked the docked Apollo and Soyuz spacecraft as they orbited the Earth in the Joint U.S./U.S.S.R. manned space mission. It also relayed live television from these spacecraft to the Earth, thus becoming the first satellite to perform such a feat.³⁰¹ After this it was positioned at 35,900 kilometers over east Africa and controlled from the Goddard Space Flight Center through a ground station in Spain. Since the down link SITE frequency of 860 MHz could interfere with terrestrial services in Europe, its antenna was pointed eastward toward India and away from Europe, thus avoiding interference with European surface broadcasts.

Technological Component: The Software

Software, the term we currently associate with computer programming language was generically used for all television programs to be beamed by the satellite during experimentation. The main aim of these programs was to bring attitudinal change and development not entertainment. Producing such programs was harder than the building of hardware. Custom made programs for enriching rural life were developed by program managers and producers with help of national and international experts. However, the task of producing such ‘software’ and having them ready to reach target audience when the ATS-6 was available, posed a series of challenges because the infrastructure was either nonexistent or poor and the producers had no clue how to create television programs, especially “sociological” programs for community viewing. In this realm seasoned producers became amateurs. Further, the technological and bureaucratic hurdles

³⁰¹ NASA News Release, Release No. 76-157, September 21 1976, record no. 005652, ATS 6 Satellite, NASA Historical Reference Collection, Washington D.C.

that experts encountered led to the creations of new organizations, government departments, and studios to manage the software side of SITE.

The iconic All India Radio (AIR) took the initial responsibility of producing programs for SITE. Having established the system for broadcasting radio programs in India since the 1930s, the space officials saw it as a natural fit for taking the mission of producing program content for SITE. The task involved the production of 1400 hours of programs to be transmitted morning and evening by the satellite.³⁰² AIR took the initial steps and established three production centers early on in Cuttack, Hyderabad and Delhi for the purpose of producing educational programs for different linguistic groups. However, the initial enthusiasm shown by AIR soon waned and the Indian space officials had a difficult relationship with AIR during program production. They found the organization to be highly bureaucratic and very conservative in its approach toward program production. Programs for SITE demanded creativity which the space officials doubted AIR could deliver, “the tendency to look upon television as radio with picture added on seems to be persistent,” noted Pramod Kale.³⁰³ Seeing the state of affairs, the space officials, recommended some changes in the structure of AIR that would make it better equipped to cope with the communication explosion. In order to prevent the formation of a “monopolistic system” where a handful of experts produced programs, Vikram Sarabhai “desired a more innovative approach of having independent producers and programmers producing programs for the system.” He had in mind something akin to

³⁰² This amount of new programming exceeds that produced by each U.S. commercial television network for its evening schedule, and a U.S. network can rely on diverse program production sources and a reservoir of experience built up over several decades. Thus meeting the demanding production schedule can be considered a major achievement by Doordarshan. See, Clifford Block, A Case Study of India’s Satellite Instructional Television Experiment (SITE), *AID Report* (January 1977), p. 7.

³⁰³ Pramod Kale, “Developing a Tool for Development: Television in India,” *Economic and Political Weekly* (July 14, 1973): 1255-1257.

INTELSAT which does not take responsibility for producing the program content but only owned, regulated, and managed the mass communication system.³⁰⁴

Because of the friction with the AIR, a separate organization called Doordarshan (a Hindi word meaning *distant vision*), initiated partly by ISRO, was given the responsibility of program production. Doordarshan formed separate committees to assist program production relating to agriculture, health and family planning. These committees were helped by institutions like the agricultural universities, teachers training colleges and Indian Council of Agricultural Research and many international experts.³⁰⁵ Other departments and agencies like the Film Division, the NCERT under the Department of Education, along with independent producers, contributed to making film material for the software content of the SITE project. A research and evaluation cell was also established in Ahmedabad and leading social scientists were consulted during the program production phase, pre testing, and the actual SITE transmission phase.

The major themes chosen for program production – agricultural improvement, family planning, national cohesion/integration, and literacy --- reflected the maladies of any developing nation state during the sixties and seventies. Though the program content was left to the Indians, the themes were jointly chosen and orchestrated by national and

³⁰⁴ Arnold W. Frutkin, "The India-U.S. Satellite Broadcasting Experiment," folder SITE, NASA Historical Reference Collection, Washington D.C.

³⁰⁵ For production of programs, the base production centers, at Hyderabad which produces programs for Andhra Pradesh and Karnataka (in languages Telugu and Kannada), in Cuttack which produces programs in Oriya Language and in Delhi which produces programs in Hindi for Rajasthan, Mahdya Pradesh and Bihar clusters were set up. These are small studios which capsule the program in advance and keep up a regular flow of tapes to Ahmadabad for direct telecast. A. Shroff, *SITE: Software Aspect in Satellite Instructional Television Experiment*, SITE Winter School, (January 16-28, 1976), Space Applications Centre, Indian Space Research Organization, Ahmadabad, India, p. 87.

international experts mostly emanating from the United States.³⁰⁶ The collaborative venture is clear when Sarabhai “accepted confidential Ford Foundation/Delhi offer to draft broad outlines of master plan for software programming, production, evaluation and training.”³⁰⁷ The choice of family planning as one of the key programs was planned by Frank Wilder, Ford Foundation Consultant in Mass Communications to the Department of Family Planning, Government of India.³⁰⁸ During the sixties the rising population was seen as a constant threat to the development of India. Recorded evidence of the possibility of using a satellite for these purposes appears in a report by Wilder who feared that the increasing population of India could “throttle and destroy” the emerging nation state. Among all the world’s nations seeking to control their burgeoning populations, India faces the largest and most difficult task,” he said, adding that “on India’s ability to achieve that performance level may well rest the economic, political and social fate of all of Asia, if not of the world.” The theme of national cohesion was equally stressed by Wilbur Schramm’s who saw it as the first and foremost step in modernization. Schramm was a close friend of Sarabhai and E.V. Chitnis, and he frequented ISRO’s Space Application Center during the planning stages of SITE.³⁰⁹ Dr. R. Lyle Webster, former

³⁰⁶ Experimental programs were also made by West German TV, British Broadcasting Corporation, Australian Broadcasting Corporation, British Council, *260 Days of SITE*, Space Applications Center, ISRO, (undated Report), SAC Library, Ahmedabad.

³⁰⁷ Confidential memorandum, Ambassador Keating, American Embassy, New Delhi, to Secretary of State, Washington D.C., July 21, 1970, “GOI Satellite ITV Program,” RG 59, Subject Numeric Files, 1970-73, box 2962, NARA II.

³⁰⁸ Frank Wilder, “Major Considerations in the Application of Satellite Communications to India’s Family Planning Programme, Discussion paper for the Joint Study Group for Satellite ETV (Indian Department of Atomic Energy and the United States National Aeronautics and Space Administration), Ahmedabad, January 25, 1968, record number 14641, folder India - SITE, NASA Historical Reference Collection, Washington D.C. For a scholarly treatment of family planning programs in India see Matthew J Connelly, *Fatal Misconception: The Struggle to Control World Population* (Cambridge, Mass: Belknap Press of Harvard University Press, 2008).

³⁰⁹ Wilbur L Schramm, *Mass Media and National Development: The Role of Information in the Developing Countries*. (Stanford: Stanford university press, 1965). This was Schramm’s monumental work and it became a bible for many technocrats to plan mass media in developing countries.

Director of Information for the U.S. Department of Agriculture, who became Ford foundation consultant on the Agriculture District Program in India, was a major supporter for the use of television programs aimed at farmers.³¹⁰ Sarabhai's views on science education and literacy was itself shaped by educational program designer Axel Horn.³¹¹ Arnold Frutkin introduced the two, and they met for the first time in New York City in 1965 for breakfast. This meeting was just a prelude. Horn visited Ahmedabad in November 1966 along with his wife for guiding the Community Science Center, an outgrowth of the Nehru Foundation for Development which was started by Sarabhai.³¹²

Before the programs were aired some of them were pre-tested in different village clusters with varying styles of presentation – straight talk documentary, drama, folk ballad, etc., to see the audience reception of these programs and what would be the best methodology. Since primary education was given first priority a lot of programs were produced for imparting knowledge related to science. Science was taught basically by taking common every day things available in a rural village, for example a local village pond was chosen to impart the properties of water, floating and sinking, waves, pollution, soil erosion, disease etc, The village postman's bicycle was taken as the starting point to discuss air pressure, air pumps, the principal of the wheel, valves springs etc; values of nutrition by taking the kitchen garden as the starting point.

³¹⁰ M. R. Dua, *Programming Potential of Indian Television: With Special Reference to Education, Economic Growth, and Social Change*, PhD Thesis, California State University, 1979.

³¹¹ He also wrote about the use of satellites in reaching the rural population with educational materials, see Axel Horn, "India: Another Frontier for ETV," *Educational/Instructional Broadcasting* (December 1969): 15-17.

³¹² Shah, Vikram Sarabhai, p. 150. Axel Horn, "Problem Solving Skills Through Science Education," in Padmanabh K. Joshi (ed), *Vikram Sarabhai: The Man and the Vision*, p. 133-139.

INDIAN VILLAGERS WATCH SITE TELEVISION PROGRAM



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Figure 26: SITE in action.

Source: NASA

SITE broadcasts began on August 1, 1975. The broadcast regularly reached over 2300 villages. Their size varied from 600 to 3,000 people, with an average of 1, 200 inhabitants. Thus, about 2.8 million people had daily access to SITE programming.³¹³ Many dignitaries from different countries visited India and viewed the SITE set up and experienced programs in rural clusters.³¹⁴ A DRS system was placed at the residence of

³¹³ Clifford Block, et.al., "A Case Study of India's Satellite Instructional Television Project (SITE)," *Agency for International Development (AID) Report* (January 1977), p. 3

³¹⁴ Notable personnel were, C. De Jager, President, COSPAR (ICSU), Gibson, Director General of European Space Agency (ESA) made a visit to five SITE villages in Rajasthan cluster (May, 1976,) NASA Administrator James C. Fletcher and Richard Barnes, (April 16-24), Commonwealth Broadcast Association (CBA), Prof. Bernard, Counsellor to CNES, France, Prof Carver, Chairman, Scientific and Technical Sub-Committee of the UN Outer Space Division, Harrie Massie, Chairman, National Committee on Space

Prime Minister Indira Gandhi's, President of India, of Arthur C. Clarke in Colombo, Sri Lanka, and also at the US embassy in New Delhi.



Figure 27: SITE in a typical village.
Source: ISRO, Satellite Application Center, Ahmadabad

SITE ended on 31 July, 1976. Seeing the success of the project the Indian officials and policy makers requested an extension of the program for one more year, but the request was not granted and the ATS-6 was pulled back over the American region.

Frutkin, who orchestrated the SITE project for NASA, said that the one year experiment proved the possibilities of the use of advanced satellites for mass communication. And he clearly knew that it would bring monetary benefits. "We took the satellite back. What was the consequence? India contracted with Ford Aerospace for a commercial satellite to continue their programs...the point is, this program not only was

an educational lift to India and demonstrated what such a satellite could do, but it brought money back into the U.S. through commercial contracts for satellites for a number of years.”³¹⁵ Years earlier in a House Committee report on the implications of satellite communications, he expressed the same view: “I’m quite confident that by virtue of our participation in this experiment, India will look to the U.S. first for the commercial and launching assistance it requires for future programs. And I think this is a very important product of our relationship.”³¹⁶ The first generation Indian National Satellite (INSAT - 1) series, four in total, was built by Ford Aerospace in the U.S.³¹⁷ Three were launched by a Delta rocket of the McDonnell Douglas Corporation and by the Shuttle, and one by Ariane in the 1980s.³¹⁸

SITE was regarded by many as a landmark experiment in the rapid upgrading of education in a developing country. It became the most innovative and potentially the most far reaching effort to apply advanced Western technologies to the traditional problems of the developing world. For the first time NASA and ISRO cooperated very closely in an effort to determine the feasibility of using experimental communication

³¹⁵ Oral History Transcript, Arnold W. Frutkin, Interviewed by Rebecca Wright, 11 January 2002, p. 24, NASA Historical Reference Collection, Washington D.C.

³¹⁶ U.S., Congress, House, Committee on Foreign Affairs, Subcommittee on National Security Policy and Scientific Developments, *Hearings, Foreign Policy implications of Satellite Communications*, 91st Cong., 1st sess., 1969, p. 38.

³¹⁷ In the year 1973 a global tender was issued for the manufacture of a hybrid satellites – direct reception and ground based network based on transmitters. Philco-Ford, Hughes Aerospace, and Fairchild of the USA and Messerschmidt-Bolkow-Blohm (MBB) of Germany submitted their bids. Philco-Ford won the bid and supplied INSAT for \$ 500 million, see Ashok Parthasarathy, *Technology at the Core*, pp. 144-148. Werner Von Braun, Vice President, Engineering and Development, Fairchild Industries Inc., visited India in May of 1973 to sell the back up satellite, but the meeting with the Indian space establishment did not yield any tangible results. He also approached Brazil, Spain, Iran, Venezuela, and to the Alaskan government for education and medical use, and finally to NASA, but his efforts ended in frustration and the back up was never built. NASA stated that “we’ve demonstrated the technical feasibility, but there’s nothing in our charter which says we are to help nurses in remote areas or educate little Indians,” see Michael J. Neufeld, *Von Braun: Dreamer of Space, Engineer of War* (New York: Knopf), pp. 463-466.

³¹⁸ Dipak C. Talapatra, “The Indian Space Program,” *IEEE Aerospace and Electronic Systems Magazine* 8, no. 2 (Feb 1993): 14.

satellite technology to contribute to the solution of some of India's major educational and development needs.³¹⁹ For NASA the experiment provided a proof that advanced technology could play a major part in solving the problems of less developed countries. It was seen as an important expression of U.S. policy to make the benefits of its space technology directly available to other peoples and also a valuable test of the technology and social mechanisms of community broadcasting. Seeing Indian states to be linguistically divided, the U.S. State Department hoped that the experiment offered India an important and useful domestic tool in the interests of national cohesion. The experiment also stimulated a domestic television manufacturing enterprise in India with important managerial, economic and technological implications. It provided information and experience of value for future application of educational programs elsewhere in the world.³²⁰

Frutkin was emphatic about the value of SITE for other developing countries "The Indian experiment is, of course, of prime significance for developing countries, those which have not been able to reach large segments of their population, those which have overriding social problems which might be ameliorated through communication and education and particularly those where visual techniques could help to bypass prevalent illiteracy."³²¹ The SITE experiment played a crucial role for India too. The results of the year-long SITE project were evaluated carefully by the Indian government. The data played a major role in determining whether India should continue to develop her own

³¹⁹ Delbert D. Smith, *Teleservices Via Satellite : Experiments and Future Perspectives Via Satellite* (Boston: Sijthoff & Noordhoff, 1978), p.120

³²⁰ Memorandum to Clement J. Zablocki by Robert F. Allnutt, Assistant Administrator for Legislative Affairs, April 24, 1969, "The India-United States Television Satellite Experiment, NARA II.

³²¹ Arnold Frutkin, "Direct/Community Broadcast Projects Using Space Satellites," *Journal of Space Law* 3, no. 1&2 (January 1975), p. 20.

communication satellite program (INSAT) or fall back on the use of more traditional, terrestrial forms of mass communication in order to transmit educational programs to the populace.³²² However, though a satellite based communication network won, direct transmission to augmented television sets for rural clusters was determined “next to impossible in terms of both the electronic hardware and TV software components.” INSAT, rather than being unique to offer direct transmission, was designed to relay programs to ground based television transmitters which then amplified and redistributed them to television sets through microwaves.³²³

The SITE project represented an important experimental step in the development of a national communications system and of the underlying technological, managerial, and social supporting elements. Following the proposal made by India, Brazil too initiated a proposal for a quite different educational broadcast experiment utilizing the ATS-6 spacecraft.³²⁴ The project was intended to serve as the development prototype of a system that would broadcast television and radio instructional material to the entire country through a government-owned geostationary satellite.³²⁵ In 1976 Indonesia became the first country in the developing world to have its own satellite system – The

³²² Delbert D. Smith, *Teleservices via Satellite*, p. 121.

³²³ Ashok Parthasarathy, *Technology at The Core*, p. 148.

³²⁴ Brazil closely competed with India for using the experimental satellite communication for reaching the masses. A special committee headed by Wilbur Schramm, was set up by NASA in 1968. The committee favored India because the village population in India, unlike Brazil, were not exposed to television sets and heterogeneity of India offered an ideal environment for testing the satellite. Arvind Singhal and Everett M. Rogers, *India's Information Revolution* (New Delhi: Sage Publications, 1989), p. 64.

³²⁵ Arnold W Frutkin, Statement before the Subcommittee on National Security Policy and Scientific Development, Committee on Foreign Affairs, House of Representatives, April 30, 1970, record no. 005652, NASA Historical Reference Collection, Washington D.C.

Palapa satellite system, manufactured by engineers at NASA and at Hughes Aerospace.³²⁶

Concluding Remarks

My story of SITE has tried to contextualize the origin, development and completion of the satellite instructional television experiment in India. What appears to be a technological collaboration in satellite mass communication between agencies – NASA and ISRO -- was in fact layered with politics. SITE was a technology that was thick with meaning and that encapsulated polyvalent agendas. Viewing the story from the American side, U.S. State Department promoted SITE as a prestigious project to offset the first Chinese nuclear test, thereby attempting, unsuccessfully, to prevent India from following suit.³²⁷ It was also an important statement that U.S. space technology could directly benefit other people, especially in developing countries. NASA's motivations were somewhat different. The officials and engineers offered SITE as a prototype to test the effectiveness of satellites for direct to home broadcasting and also to determine orbit and spectrum allocations for application satellites like ATS. In the process of this experimentation/simulation a nation-state, India, became a laboratory that could be copied in other 'third world' countries seeking 'development.' For India, SITE showed that a high technology could be used for socio-economic development. It became one justification for building a space program in a poor country--- the question became 'not whether India could afford a space program but can it afford not to have one'?'³²⁸

³²⁶ For an anthropological analysis of the Palapa satellite in Indonesia see Joshua Barker, "Engineers and Political Dreams: Indonesia in the Satellite Age," *Current Anthropology* 46, no. 5 (December 2005): 703-727.

³²⁷ India conducted its first nuclear test in May 1974 under the name "peaceful nuclear explosion – PNE,"

³²⁸ The first appearance of this rhetoric was uttered by Vikram Sarabhai at the UNCOPUS in 1968 "the question has often been asked: Can one afford to undertake space research? But I'm sure there are many

Recently postcolonial scholars have offered nuanced understanding of modernization projects in the lesser developed countries. “The Northern development agencies justified by appeals to humanitarianism their plans to bring the so-called underdeveloped societies up to the standard of living of the industrialized North, thereby ending the poverty which was seen as a consequence of the traditionalism of Southern societies.”³²⁹ From its beginnings, development was conceptualized as achievable only through the transfer to the South of Northern scientific rationality and technical expertise and the associated democratic political forms. ‘Modernization’ through science and technology is not new to the Indian subcontinent. In more than two centuries of British occupation India witnessed a huge incursion of technologies - railways, telegraph, telephone, radio, plastics, printing presses for ‘development’ and extraction.³³⁰ The geosynchronous satellite in post-colonial India can be seen as an extension of the terrestrial technologies that the British used to civilize/modernize a traditional society. In this case the U.S. replaced the erstwhile imperial power to bring order, control and ‘modernization’ to the newly decolonized states through digital images using satellite technologies that were far removed from the territorial sovereignty of nation-states.³³¹

here like myself, who will ask: can anyone afford to ignore the applications of space research?” *Practical Benefits of space exploration: A digest of papers presented at the UN conference on the exploration and peaceful uses of outer space*, Vienna, 1968 (United Nations: New York, 1969).

³²⁹ Sandra Harding, *Science from Below: Feminisms, Postcolonialities, and Modernities* (Durham: Duke University Press, 2008), p. 142.

³³⁰ See Daniel R. Headrick, *The Tools of Empire: Technology and European Imperialism in the Nineteenth Century* (New York: Oxford University Press, 1981).

³³¹ This becomes more evident when one gives a careful attention to the wordings--unlimited civilizing, modernization, development etc, in some documents that were prepared during the planning of SITE. Of particular importance see the undated document by Arnold W. Frutkin, “The India-U.S. Satellite Broadcasting Experiment,” record no. 14641, International Cooperation and Foreign Countries, folder SITE, NASA Historical Reference Collection, Washington D.C.

Concluding Thoughts

Through the case studies of four technological systems – optical tracking of satellites, sounding rockets, instructional television through a geosynchronous satellite, and a launch vehicle, I have attempted to tell the story of the origins and development of the Indian space program during the formative and critical years (1955-1976). Institutionalized, in different geographic regions of India – Naini Tal, Thumba, Ahmadabad, Sriharikota, -- these systems got embedded in the broader political, economic, and social life of India and formed nodes around which existing and new scientific and technological communities were formed. This organic, highly networked community in turn negotiated, appropriated, and incrementally developed a space program to suit the socioeconomic and strategic demands of a new nation state. During the two decades of its development one could visibly see the shifting priorities of the space program shaped both by the compulsions and desires of the new elite to modernize India and the vicissitudes of global Cold War. With the scepter of communism encroaching the newly decolonized states, the United States, felt the need to extend its arms into India to spread liberal democratic and capitalist ideals. Beginning in the early nineteen fifties, ‘modernizers’ – from private foundations, educational institutions, a suit of agencies, US State Departments Agency for International Development (AID), and others reasoned that if India developed along capitalist lines, then communism would be kept at bay and the rapid economic growth would develop India and offer a visible model for other developing nations – mainly the decolonized Afro-Asian states. In a geopolitical climate where India embraced a ‘non-alignment’ policy, the United States levered its science and technology as “soft power” to lure the Indian native elite toward the U.S. In

this context a repertoire of technologies in the domains of – nuclear, space, molecular biology, agricultural improvement, oceanography, electronics, etc -- were used to engage with disparate elite groups for the common cause of modernizing India and prevent the elites from being attracted to the Soviet camp. However, the technology flow was highly restricted and license production or technology transfer was never entertained. In such a climate of various technology controls and the emerging geopolitical situation there was a fuller determination among the native elite to embrace the ethos of self-reliance. If building infrastructure was the dominant leitmotiv of the fifties and sixties, national security and strengthening of indigenous firms were the dominant leitmotifs of the seventies. In the mid-fifties a space program was non-existent in India. Two decades later, by 1975, India had gone nuclear and the space program was acquiring the technological maturity to build rockets for civilian and military applications and satellites for earth observation and communication purposes. The transformation, both in scientific and technological, was ushered by the emergence of a new elite, mostly western trained, who formed wide networks, both domestic and international, for establishing a space program. The transformation was also seen on the political and on the ideological front. Having been involved in three wars in the subcontinent the Nehruvian approach to foreign policy of mutual coexistence was changed to a more aggressive global player with regional hegemony under Indira Gandhi, all bent toward making India a powerful center of south Asian politics. Ideologically, Non-aligned movement lost its relevance when India openly forged relations with Soviet Union for technology aid - especially in defense purchases, soon after the 1971 Indo-Pak war.

A new elite -- breed of engineers and technologists, came of age during the evolution of the India's space program. The core Indian experts who orchestrated the program received extensive training from prestigious institutions and at NASA facilities. Many who earned their PhD's in the US, were invited by Vikram Sarabhai to initiate and head core facilities and help toward coordinating and building a vast infrastructure to develop a space program in India. Their training in select US facilities and the broader networks that were established facilitated frequent visits to gather knowledge – in the form of reports, workshops, conferences, and personnel exchanges. It is striking that while the pioneers of the Indian program were educated in Britain under colonial rule, the new, post-independence generation mostly received their education and some training in the United States. The case studies dealt with in the dissertation also reveals some mundane aspects of how technology and knowledge circulation happens -- how visas were granted, per-diems paid, flight plans made, how technology moves etc. Also by selectively opening the American facilities for scientists and technologists it created “taste or desire” for the Indians to return to America. India today indigenously manufactures highly sophisticated remote sensing and communication satellites; however, important components and subsystems are manufactured mostly by US business corporations. In some areas, the knowledge flow was highly restricted. The case of negotiating the procurement of Scout launch vehicle highlighted the intricate mechanism of transfer when it comes to dual use technology. The United States government through the Office of Munitions Control (OMC) handled export license applications on a case by case basis and generally rocket technology and related subsystems were never cleared.

Space science programs started in India as a cooperative scientific endeavor with the spotting of artificial satellites, chasing elusive cosmic rays, and mapping high altitude winds. The data gathering mission that began during IGY was gradually extended to sounding rocket missions in coastal Thumba in the early 1960s. Thumba became a nodal point for attracting world renowned scientists and the establishment of TERLS put India on the space map of the world. The U.S. State Department used NASA as a tool of foreign policy to engage with the nascent space establishment and to lure the experts to get training at select NASA field centers for fostering scientific and technological collaboration. This was one way of aligning Indian scientists with American colleagues and practices, and also to know about Soviet programs. It also helped them to work with the other international scientific communities that were collaborating at Thumba. The process involved the willing consent of the Indian national elite – almost all western trained scientists – Vikram Sarabhai, Vainu Bappu, Homi Bhabha, E.V. Chitnis, and others. They sought to master the evolving new frontier of space science and technology, which the elites viewed as prestigious endeavors – it gave visibility for the new nation state and helped to project leadership in the comity of newly decolonized states in the Afro-Asian nations. The native elite were particularly attracted to American overtures in space science and technology. They were impressed by NASA's commitment to openness and sharing, albeit in a limited way, of technology and data, and the willingness to provide expertise. This was sought after by the native elite as foundational for building their own capabilities. In the early sixties India experimented with sounding rockets donated by other countries but by mid sixties India incrementally acquired the infrastructure to manufacture sounding rockets indigenously. By 1975, India could boast

of a fleet of indigenous sounding rockets for gathering atmospheric data and space sciences inside ISRO attained maturity to handle complex scientific missions. Recently, *Chandrayaan I* (Moon craft) -- a scientific moon mission, was launched by India on its indigenous rockets in the year 2008. The space craft carried two NASA-built instruments on its maiden voyage to the moon. It was a proud moment for both countries, and a fitting tribute to NASA's contribution to a space program that it helped to found with the Indian scientific and engineering elite in the early 1960s.

The early thrust on space science slowly gave way to space applications. In a poor country with starving millions a space science program had to be justified for government largesse. Here is where the genius of scientist and technocrat Vikram Sarabhai comes into play. He successfully tweaked esoteric missions as obligatory passage points that every developing country had to go through – mainly to create viable institutions and the building of infrastructure. This argument ensured him state support and patronage from private foundations. In a climate of increasing internal domestic constraints – over population, famine, illiteracy etc, the space science program gets a lesser priority over space application projects. In the larger framework of 'modernization for development' already entrenched in the new nation state, the nascent space team selectively appropriated the tenets of modernization into their evolving space program and progressively advocated high-technology as a vehicle to develop India. The use of space technology for winning the hearts and minds of people in developing regions thrilled the US State Department and NASA. The United States wanted to channel the technology flow to augment the nascent space program to yield societal benefits and to secure future markets for high technology. Ford Aerospace got a contract to make India's first

generation communication satellite and also paid for launches. Engagement during SITE and remote sensing experiments selectively tied the Indian space establishment with the business enterprises of the United States. Rural television was an outgrowth of this and it culminated in the SITE project. The “digital revolution” in India today has moorings in the SITE experiment. Proliferation of firms in the electronics industry to manufacture television sets and concurrent hardware clearly played a major part in the growth of electronics. Levering the focus on agricultural improvement (Green Revolution) new facilities were created for the development of remote sensing -- a “plough in the sky.” What started as an aerial mission using Hasselblad cameras matured into a remote sensing satellite program within ISRO. After the successful launching of Bhaskara I and II experimental low earth orbiting satellites in 1979 and 1981, India today has twelve remote sensing satellites under the Indian Remote Sensing (IRS) satellite system, making it the largest constellation of remote sensing satellites in the world.

While space application was given a major thrust, India had other parallel priorities as well. The internal geopolitical situation of having lost a war with China (1962), and the Indo-Pakistan war (1965), and having to face a nuclear China, made a nuclear deterrent increasingly attractive. While planning a program using application satellites, Sarabhai recruited a stream of western trained technologists mostly from United States, to kick start an indigenous rocket program. The flow of technology now shifts from the United States to those who were willing to cooperate with India. France becomes a key partner in this mission, assisted by Japan and Germany. Locked in the cold war, where the Soviet Union and the USA were attempting to maintain their presence, India astutely played the game to build her own space program with scarce

resources by constantly forming networks. This tension gets manifested in how the Indian space program evolves. In this state of affairs United States and India become partners in an uneasy tango where the arms cooperated but not the legs. When India's own wishes were not compatible with what America had to offer, India quickly switches partners – Soviet Union, France, Germany, and others to augment a space program with ballistic missile abilities. By the time of Sarabhai's death India's space program was heading in a direction that alarmed the United States. Inquires into nose cone, solid propellants and precision guidance packages in the early 70s clearly indicated India's ballistic missile ambitions and the growing nuclear program only confirmed it. On the political front the Indo-Pakistan war (1971) brought a wedge between US and India. The Foundations, after several years of operation in agriculture and population control, were leaving and economic aid virtually came to a standstill. The United States had vested interest in India during the fifties and sixties. The real estrangement actually happens in the 1970s. While the US was slowly withdrawing, the Soviet Union drew closer to India. India's first satellite *Aryabhata* – an astronomical satellite, was launched by Soviet Union in 1975 and also launched two remote sensing satellites – Bhaskara I and II. Close relations were also forged with France for the development of liquid fueled rockets. Though France and Soviet Union extensively engaged with India after relations cooled with the United States' the native elites preferred working with Americans—as this dissertation shows only too well. The policy of non-alignment during global cold war offered the maneuverability to switch partners easily without jeopardizing their status quo.

Epilog

Transnational Networks and Knowledge Flows

The case studies dealt with in the dissertation highlight the circulation of knowledge between “metropolis” and “periphery.” Rather than a unidirectional flow, where the periphery was always at the receiving end, there is a dynamic feedback of knowledge from “periphery” to “center.” India received space related technology and at the same time by engaging with India and directing space technology for socio-economic benefits, Americans learned about what a space program should be in developing countries. It was eye opening for many US experts to the realities of Indian life. Undoubtedly Vikram Sarabhai made a profound impact on Arnold Frutkin. He profusely cites Vikram Sarabhai’s work in his own book and he too appropriates the modernization language. Commenting on the SITE experiment, Frutkin stated that “this would be the first experiment in the use of a satellite for widespread educational instruction and the results, if successful, would be applicable elsewhere in the less developed world. This alone made the project useful to NASA.”³³² A perceptive observation of this kind of feedback loop was expounded by Kapil Raj, a historian of science and technology, when he says that “instead of a linear, unidirectional model of cross-border knowledge flows, the encounter between center and periphery is now seen as a face to face transaction

³³²Memo, From NEA/INC—David T. Schneider, to NEA—Mr. Van Hollen, February 5, 1970, “Status of the Educational Satellite Program in India, RG 59, Records Relating to India 1966-1975, box 25, NARA II.

between agents from different polis in which they collaborate in the co-production of scientific knowledge according to specific needs, interests and agendas.”³³³ Although Raj’s setting is colonial India and the co-production was in the realms of scientific knowledge, his observation resonates well with knowledge flow between United States and India and vice-versa.

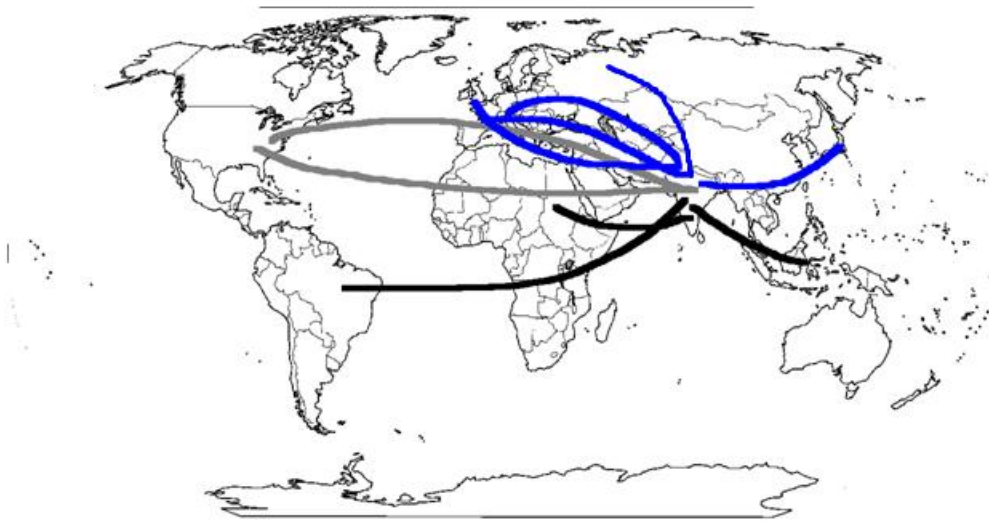


Figure 28: International networks and knowledge flows

Grey – From the United States of America

Blue – From European countries – UK, France, and Germany and also Japan

Black – Periphery -- Periphery Collaboration – India with Brazil, Indonesia and African countries.

The transnational flow of knowledge and technology was made possible by the elites who either received their education or training in the US or both (see the below table). The network established by Vikram Sarabhai and Homi Bhabha was continued by other scientists and technologists who spearheaded the space program. Though they acted as crucial nodes around which networks were formed, the Indian elite, however, were not denied agency. At every stage they selectively appropriated the

³³³ Kapil Raj, *Relocating Modern Science: Circulation and the Construction of Knowledge in South Asia and Europe, 1650-1900* (Palgrave Macmillan, 2009), p. 223.

knowledge and technology for building a space program that addressed core needs of a developing nation state. While the United States played a critical part during the early stages of India's space program, India was simultaneously building relations with Soviet

Table 7: Education and Training in the United States

Name	Education/Training
Raman Pisharoty	Father of Remote Sensing in India PhD from UCLA US weather Bureau offices in Washington D.C. Los Angeles , New Orleans and the Hurricane Forecast Center at Miami,
A.E. Muthunayagam	Father of liquid Propulsion in India PhD - Purdue. Training at AMES, and other facilities
Y.J. Rao	Project Manager – SLV 3 (early stages) PhD – Minnesota Trained at many U.S. facilities
P.D. Bhavsar	Sounding rocket research and establishment of TERLS Post-Doc at Minnesota Trained at Wallops, AMES
HGS. Murthy	Sounding rocket research and establishment of TERLS PhD from Minnesota Trained at many NASA facilities
Vikram Sarabhai	Father of the Indian space program PhD, Cambridge. Visiting faculty at MIT.
MGK Menon	PhD Bristol, UK . Led the space program after Sarabhai's sudden demise.
Pramod Kale	Trained at GSFC and other NASA facilities. Played critical role in the SITE project and INSAT.
M.R. Kurup	Made many trips to the US for developing solid propulsion motors and propellants.
Vasant Gowarikar	Birmingham University, UK. Made many trips to NASA facilities. Worked extensively on the satellite launch vehicle.
Abdul Kalam	Received 6 month training at Wallops, Ames, GSFC. He led the launch vehicle program after Y.J. Rao. He orchestrated the Integrated Guided Missile Development Program (IGMDP).
Yash Pal	PhD (Physics), from MIT. Played an instrumental role in the SITE project.
Binod c. Agrawal	PhD from Minnesota (Anthropology). Was involved in SITE project.
Vainu Bappu	Astronomer PhD from Harvard
S.C. Gupta	Father of inertial guidance in India. PhD from University of Pennsylvania
E.V. Chitnis	Invited to join Bruno Rossi's team at MIT (1958-61).
Satish Dhawan	PhD (aeronautical engineering) - Caltech

Union, Germany, France, Japan, UK, for acquiring technological know-how and hardware that were generally denied by the United States. The appropriation of liquid technology from France and guidance package from Germany is a case in point.

Moving beyond the “metropolis – periphery” networks, India’s aspiration to be a leader among the developing countries, which was equally promoted by the United States during the sixties, led to India becoming a center for training scientist and technologists from other developing countries. This is very evident during NASA’s collaboration with India wherein India trained a host of nations in satellite ground stations and the use of satellites for educational purposes (see the chapter on SITE). The migration of Indian scientists to Brazil for kick starting a meteorological program³³⁴ and expert advice offered to other developing countries in space technology throws light on the “periphery” – “periphery” collaboration, hitherto unexplored in space history.

³³⁴ Interview Ashok Maharaj with Fernando de Mendonca (father of Brazilian space program), 28 April 2008. NASA Historical Reference Collection, Washington D.C. India trained scores of engineers from surrounding Afro-Asian region, at Space Application Center, Ahmedabad, in the field of satellite communication.

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Dr. Bhatia, Retired scientist, ISRO

Prof. Praful Bhavsar, retired scientist, ISRO,

Jacques Blamont, eminent scientist, CNES, Paris,

Chandrasekhar, Former scientist, ISRO,

E.V. Chitnis, Former Director of Space Application Center, ISRO

Padmanabh Joshi, Archivist, Sarabhai Papers, Ahmadabad

Abdul Kalam, Project Director SLV-3, former President of India

Pramod Kale, former Director of Space Application Center, ISRO

K. Kasturirangan, Former Chairman, ISRO.

Yash Pal, Retired scientist, ISRO

N. Pant, Retired scientist, ISRO.

Radhakrishnan, Retired scientist/payload specialist, ISRO,

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